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CONTENTS

Quantitative Analyses of the Essential Amino Acids of Royal Jelly and Some Pollens ..... NEVIN WEAVER AND KENNETH A. KUIKEN 635
Time Factors in Mating Systems for Honey Bees ..... MARTIN S. POLHEMUS AND O. W. PARK 639
Control of *Petrobia latens* in the Imperial Valley of California ..... H. T. REYNOLDS AND J. E. SWIFT 642
DDT Spray Formulations for Control of White-Fringed Beetles ..... IRVING KEISER AND CHAS. F. HENDERSON 646
Chemical Control of Sweetpotato Insects in Hawaii ..... MARTIN SHERMAN 652
Toxicity of Various Compounds as Fumigants to Eggs and Larvae of the Oriental Fruit Fly ..... J. W. BALOCK AND D. L. LINDGREN 657
Dips for the Citrus Blackfly as a Possible Treatment for Mexican Limes Boxed for Export ..... J. G. SHAW AND M. ORTIZ 660
Insecticide Tests Against Plum Curculio ..... W. D. WYLIE 665
White Grub Control in Strawberries ..... G. EDW. MARSHALL 668
Studies with Acaricides for Control of Mites in Apple and Pear Orchards in Southern California ..... MARTIN M. BARNES 672
Control of Peach Tree Borer and Lesser Peach Tree Borer in New York ..... E. H. SMITH 685
Residue Studies on DDT and Parathion Applied to Lettuce for Control of the Six-spotted Leafhopper ... M. J. SLOAN, W. A. RAWLINS AND L. B. NORTON 691
Factors Affecting the Loss of DDT and Parathion Residues on Lettuce ..... M. J. SLOAN, W. A. RAWLINS AND L. B. NORTON 701
DDT and Parathion for San Jose Scale Control ..... W. J. O'NEILL 709
Field Tests with Ethylene Chlorobromide on Wireworms ..... M. W. STONE AND F. B. FOLEY 711
The Toxicity of Cumulative Spray Residues in Soil ..... EDWIN GOULD AND ELWOOD O. HAMSTEAD 713
One Application Control for Cattle Lice ..... J. L. LANCASTER, JR. 718
Experiments with Screw-Worm Flies Sterilized by X-Rays ..... R. C. BUSHLAND AND D. E. HOPKINS 725
Fly Control Experiments in Massachusetts in 1950 ..... STEVE MOORE, III, ALBERT H. TOCZYDLOWSKI AND HARVEY L. SWEETMAN 731
Effect on House Flies of Intermittent Exposures to Small Amounts of DDT Residues ... ROBERT A. HOFFMAN, A. R. ROTH AND ARTHUR W. LINDQUIST 734
Criteria for Evaluating Insecticidal Phytotoxicity—Aerial Growth ..... J. E. CASIDA AND T. C. ALLEN 737
Criteria for Evaluating Insecticidal Phytotoxicity—Root Growth ..... J. E. CASIDA AND T. C. ALLEN 741
Two Systemic Insecticides for Control of the Pea Aphid ..... T. E. BRONSON AND J. E. DUDLEY, JR. 747
Toxicity of Certain Phosphorus Compounds to Cotton Insects ..... J. C. GAINES, E. E. IVY AND C. E. KING 750
Status of Oriental Fruit Fly Parasites in Hawaii ..... ROBERT VAN DEN BOSCH, H. A. BESS AND F. H. HARAMOTO 753
Parasitization of Dipterous Leaf Miners in Cantaloups and Lettuce in the Salt River Valley, Arizona ..... ORIN A. HILLS AND EDGAR A. TAYLOR 759

A Biological Check Method for Evaluating the Effectiveness of Entomophagous Insects.....PAUL DEBACH, C. A. FLESCHNER AND E. J. DIETRICK 763
Boll Weevil Infestations and Control in Eastern Arkansas in 1950.....CHARLES LINCOLN 766
Control and Eradication of Pest Thysanurans.....STEVE MOORE, III, AND HARVEY L. SWEETMAN 770
Tests of Lindane and Other Insecticides for Control of *Lygus oblineatus*.....ZIA-UD-DIN 773
A Modified Probit Method for Comparison of Insecticides for Wireworm Control.....HORACE P. LANCHESTER 779
Further Studies of the Control of Insects of Red Clover in New York.....GEO. G. GYRISCO AND D. S. MARSHALL 785
Control of the Sweetclover Weevil in Indiana.....M. CURTIS WILSON 792
European Corn Borer Damage to Grain Sorghums.....REGINALD H. PAINTER AND DALE E. WEIBEL 796
Vanda "Miss Agnes Joaquim," a Host of *Dacus dorsalis*.....N. E. FLITTERS 799
Dieldrin as a Chemical Control Material on Community Fly Control Programs.....H. F. SCHOOF, R. E. SIVERLY AND J. H. COFFEY 803

SCIENTIFIC NOTES:

Comparative Toxicity of Allethrin and Natural Pyrethrins.....G. T. BOTTGER 808
Parathion to Kill Fruit Fly Maggots in Cherries.....FRANKLIN SHERMAN, III 809
Prospaltella as a Secondary Parasite of Mealybugs.....STANLEY E. FLANDERS 810
Preliminary Insecticide-Fertilizer Soil Treatments.....PHILIP C. STONE AND GEORGE E. SMITH 810
Tests with the Bowen Vat-Side Method for Determination of Toxaphene in Cattle Dips.....E. W. LAAKE AND J. C. CLARKE 811
Typhus Control at Ports in Japan and Korea After World War II.....FRANKLIN S. BLANTON AND TADASHIO G. TANI 812
Effectiveness of Insect Repellents Against Black Flies.....B. V. TRAVIS, A. L. SMITH AND A. H. MADDEN 813
Control of Body Lice on Prisoners of War at U. S. Ports During World War II.....FRANKLIN S. BLANTON 814
Potato Psyllid Selection of Host Plants.....R. L. WALLIS 815
Zinc Ethylene Bisdithiocarbamate Toxic to Pickleworm and Melonworm.....W. J. REID, JR. 817
Hemisarcoptes malus, a Predator of Forbes Scale.....S. A. SUMMERLAND AND D. W. HAMILTON 818
Technique in Jarring for Plum Curculio.....W. D. WILEY 818
New Host and Distribution Records for *Amblyomma inornatum*.....R. B. EADS 819

OBITUARY:

William Andrew Thomas..... 821
Edward A. Schwing..... 822
REVIEW..... 762, 820

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JOURNAL OF ECONOMIC ENTOMOLOGY

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Vol. 44 October, 1951 No. 5

Quantitative Analysis of the Essential Amino Acids of Royal Jelly and Some Pollens[1]

NEVIN WEAVER and KENNETH A. KUIKEN[2,3]

Pollen and honey are the natural foods of the honeybee. Pollen is necessary for larval development and, when pollen is scarce, a much larger hive population may be attained if supplementary pollen is fed to the bees. Since the collection of pollen is a rather expensive and troublesome task, beekeepers have experimented with a wide variety of foods in a search for a pollen substitute. However, no substitute for pollen as a food for bees has been found. Quantitative vitamin studies have not provided a complete explanation for the failure of other foods to maintain honeybee colonies (Haydak 1945, 1949). It is quite possible that some unique combination of amino acids, characteristic of pollen proteins, can account for the apparent dependence of the honeybee on this source of food. Although this possibility has been recognized for a long time, there is only limited quantitative data in the literature on the amino acid composition of pollen proteins. Vivino & Palmer (1944) fed ether-extracted pollen to rats and concluded that tryptophan and methionine were not present in optimum quantities for rat growth. Filter paper chromatography was used by Auclair & Jamieson (1948) for a qualitative analysis of amino acids in dandelion, willow and mixed pollens. These authors were unable to identify tryptophan in the free amino acids or protein hydrolysate of dandelion pollen or in the protein hydrolysate of willow pollen. Quantitative data for 12 amino acids in hand-collected sweet corn pollen were reported by Sarker *et al.* (1949).

Royal jelly, a secretion of the pharyngeal glands of adult worker bees, is used as a larval food. All larvae receive this food during the first two days of life. Thereafter, only those larvae which are to develop into queens continue to receive royal jelly (Nelson *et al.* 1924) though worker larvae may receive some glandular secretion of a different kind in their food (Haydak 1943). The queen larvae grow to about twice the size of worker larvae and pupate one day sooner (Bertholf 1925). It is possible that quantitative differences in the amino acids of royal jelly and pollen account, in part, for these effects. This concept is supported by the work of Wilson (1941, 1945a, 1945b, 1946) and Wilson & Birch (1944) which indicates that an excess of alanine, arginine, cystine, methionine, phenylalanine, proline, tryptophan or tyrosine in the diet of *Drosophila melanogaster* larvae either stimulates the rate of growth or accelerates moulting. Royal jelly was fed to rats as the only source of protein by Melampy & Jones (1939). These authors found that the proteins had a digestion coefficient of 81 per cent and a biological value of 75 per cent. By chemical tests Townsend & Lucas (1940) identified eight amino acids from royal jelly. Pratt & House (1949) used filter paper chromatography for a qualitative determination of the amino acids of royal jelly. Histidine, hydroxyproline and tryptophan could not be identified.

MATERIALS AND METHODS.—Worker larvae approximately one day old were grafted into a queenless, broodless colony. After a day they were transferred to the third story of finishing colonies. Three days later the queen larvae were discarded; the royal jelly was removed to a screw top jar and placed under refrigera-

[1] Technical Contribution No. 1485 Texas Agricultural Experiment Station.

[2] The authors wish to thank Mary Trant for technical assistance in conducting these assays.

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tion immediately. Approximately half of the cells were sealed at the time the royal jelly was taken. The average yield was 325 mg. royal jelly per cell. Royal jelly changes in vitamin, and possibly in protein, content with each successive day of larval development (Gontarski 1949; Haydak 1943; Haydak & Vivino 1950), but since queen larvae in all stages are given a super-abundance of food, the royal jelly represented a composite of the food from the time the graft was made until the time of collection.

Post oak, *Quercus stellata* Wang, pollen was hand collected. Limbs bearing open flowers were placed in a pollen drier which maintained a temperature about 15° F. above the temperature of the room. After a day of desiccation the pollen was shaken out and strained through successively finer screens to remove the trash. All other pollen samples were collected in a pollen trap (Schaefer & Farrar 1946), placed in the pollen drier overnight, and then stored in screw top jars. Analyses were conducted for the essential amino acids in royal jelly, the post oak pollen, and bee collected pollens of white larkspur, *Delphinium virescens* Nutt., willow, *Salix nigra* Marsh, bluebonnet, *Lupinus texensis* Hook, with possibly some pollen of the closely related *L. subcarnosus* Hook, partridge pea, *Cassia fasciculata* Michx. and a mixed pollen in which willow and a species of elm predominated. The hand collected post oak pollen acquired a decidedly rancid odor within a few days after it was collected. There was no noticeable change in any of the bee collected pollens.

The pollens were ground in a mortar, the royal jelly stirred well, before samples were taken. Crude protein was calculated by multiplying the Kjeldahl nitrogen value by a factor of 6.25. Two grams of each material were hydrolyzed by refluxing 24 hours with 200 ml. of 6 N HCl. The excess HCl was removed by vacuum distillation, the hydrolysates diluted to 100 ml., filtered, and stored in the refrigerator until used for amino acid analyses. Alkaline hydrolysates were made by the method of Kuiken *et al.* (1947) for the tryptophan determinations.

Valine, leucine, and isoleucine were determined with *Lactobacillus arabinosus* 17-5 (Kuiken *et al.* 1943). *Leuconostoc mesenteroides* P-60 was used to determine methionine (Lyman *et al.*, 1946), arginine, lysine and phenylalanine (Kuiken & Lyman, unpublished methods). *Streptococcus faecalis* R. was used to determine threonine, histidine (Lyman *et al.*, 1947), and tryptophan (Kuiken *et al.*, 1947). L amino acid standards were used in the assays for leucine, isoleucine, arginine, lysine and histidine; DL standards were used in the other assays.

RESULTS AND DISCUSSION.—Data for the crude protein and essential amino acid content of royal jelly and six pollens are presented in table 1. The amino acid values are expressed as per cent of amino acid found in the crude protein. From 42 to 46 per cent of the crude protein of the pollens and royal jelly is accounted for

Table 1.—The essential amino acid content of royal jelly and six pollens (amino acid content expressed as per cent of crude protein).

COMPONENT	SOURCE						
	Royal Jelly	Willow Pollen	Larkspur Pollen	Post Oak Pollen	Bluebonnet Pollen	Patridge Pea Pollen	Mixed Pollen
Crude Protein (N×6.25)	12.17	22.57	22.66	27.68	32.08	33.32	19.70
Arginine	5.1	5.6	4.4	6.4	4.9	5.0	5.7
Histidine	2.2	2.0	3.5	2.4	2.2	2.6	2.4
Isoleucine	5.3	5.2	5.1	4.7	5.5	5.8	4.5
Leucine	7.7	7.0	6.9	7.2	7.4	7.5	6.7
Lysine	6.7	5.9	6.3	7.0	6.0	6.8	6.3
Methionine	1.9	1.9	1.8	1.7	2.1	2.1	1.8
Phenylalanine	4.1	3.7	4.4	4.1	4.0	4.3	3.9
Threonine	4.0	3.8	3.9	4.0	4.3	4.3	4.0
Tryptophan	1.3	1.5	1.4	1.2	1.4	1.6	1.3
Valine	6.7	6.0	6.0	5.5	5.6	5.9	5.7

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by the essential amino acids. It will be noted that, though there are variations between pollens of different species, the variation in amino acid content is not extreme. Histidine, with a range of from 2.0 per cent in willow to 3.5 per cent in larkspur, is exceptional. The amino acid and protein content of the pollens of the two legumes were very similar.

Royal jelly, though of animal rather than of plant origin, did not differ greatly from the pollens in essential amino acid content. Valine and leucine were slightly more plentiful in royal jelly than in any of the pollens, but the remaining amino acids fell within the range of variation between different pollens. Nothing is known, of course, of the availability of the amino acids of pollen or royal jelly to larvae, but in essential amino acid content there is no appreciable difference in the two foods.

There is a fairly great variation in the crude protein content of the various pollens. Royal jelly has considerably less protein than any of the pollens that were included in this study, but some pollens are poorer sources of protein than royal jelly. Todd & Bretherick (1942) found that the crude protein content of pollens of 34 species ranged from 7.02 to 29.87 per cent. Since in preparing food for worker larvae, bees add nectar or diluted honey and possibly glandular secretions to pollen, it is probable that worker larvae receive a smaller percentage of protein than is found in the queen food, royal jelly. Analyses for the protein in worker brood food have yielded conflicting results (Haydak 1943).

The essential amino acid composition of pollen is compared with that of three protein rich foods in table 2. There are no great differences to be noted, and it would appear from this consideration alone that these proteins would be of approximately equal value for bee feeding. Soy bean flour has been mixed with pollen, sugar and water as a food supplement for honeybee colonies, and increased brood rearing and honey production have resulted (Farrar, 1944). However, high larval mortality has been observed when this mixture was used (Weaver, unpublished).

It is recognized that the amino acid requirements of the bee are not known, and it is therefore quite possible that a requirement for some amino acid other than those included in this study might account for an apparent pollen requirement of the bee. There is evidence in work with other insects of requirements of glycine (Goldberg & DeMeillon, 1948) and cystine (Goldberg & DeMeillon 1948; House 1949). It is probable that any one of the proteins listed in table 2 would supply adequate amounts of these amino acids.

Table 2.—The essential amino acid content of pollen and some other foods (amino acid content expressed as per cent of crude protein).

Component	Source				
	Average Pollen[1]	Sweet Corn Pollen[2]	Soy-bean Flour[3]	Casein[4]	Whole Egg Powder[5]
Crude Protein (N×6.25)	26.34	26.88*	48.41	100	70.69†
Arginine	5.3	4.7	7.7	3.4	6.2
Histidine	2.5	1.5	2.3	2.7	2.4
Isoleucine	5.1	4.7	5.3	5.7	5.8
Leucine	7.1	5.6	8.0	8.7	9.0
Lysine	6.4	5.7	6.6	6.9	7.5
Methionine	1.9	1.7	1.4	2.8	3.3
Phenylalanine	4.1	3.5	5.1	4.8	4.8
Threonine	4.1	4.6	3.9	3.9	4.7
Tryptophan	1.4	1.6	1.5	1.2	1.5
Valine	5.8	6.0	5.3	6.6	6.8

[1] Average of pollen data from table 1.
[2] Sarkar *et al.* (1949).
[3] Kuiken and Lyman (1949).
[4] Cole (1950) Tryptophan values from Kuiken *et al.* (1949).
[5] Lyman and Kuiken (1949).
* Moisture-, ash-, lipid-free basis.
† Defatted powder.

Honeybees may be unable effectively to digest certain of the proteins that might be used as pollen substitutes. In this regard it should be noted that soy beans contain a proteolytic enzyme inhibitor (Ham & Sandstedt, 1944), which interferes with the digestion of soy bean protein by higher animals. Carefully controlled processing is necessary to inactivate this inhibitor without reducing the food value of the protein (Riesen *et al.* 1947). Another factor to be considered is that bees might require some unique peptide combination of amino acids, such as strepogenin (Woolley 1948), for optimum nutrition.

SUMMARY AND CONCLUSIONS.—Six pollens and royal jelly were assayed microbiologically for essential amino acid content. The data were expressed in terms of the amino acid contained in the crude protein, and when compared on this basis no marked differences in amino acid distribution were noted. A comparison with soy bean protein, casein and whole egg protein indicated that these products have a very similar essential amino acid composition.

LITERATURE CITED

Auclair, Jacques L. and Cecil A. Jamieson. 1948. A qualitative analysis of amino acids in pollen collected by bees. Science **108:** 357–8.

Bertholf, L. M. 1925. The moults of the honeybee. JOUR. ECON. ENT. **18:** 380–4.

Cole, W. H. 1950. Cooperative determination of the amino acid content, and the nutritive value of six selected protein food sources. Rutgers University, New Brunswick, New Jersey.

Farrar, C. L. 1944. Productive management of honeybee colonies in the northern states. U.S.D.A Circ. **702.**

Golberg, L. and B. DeMeillon. 1948. The nutrition of the larvae of *Aëdes aegypti.* Linnaeus. IV. Protein and amino acid requirements. Biochem. Jour. **43:** 379–87.

Gontarski, H. 1949. Microchemical investigation on brood food, and the problems of the genesis of the queen honeybee. Hessiche Biene **85:** 89–92. (Seen only in abstract in Bee World **31:** 39. 1950.)

Ham, W. E. and R. M. Sandstedt. 1944. A proteolytic inhibiting substance in the extract from unheated soy bean meal. Jour. Biol. Chem. **154:** 505–6.

Haydak, Mykola H. 1943. Larval food and development of castes in the honeybee. JOUR. ECON. ENT. **36:** 778–92.

Haydak, Mykola H. 1945. Value of pollen substitutes for brood rearing of honeybees. JOUR. ECON. ENT. **38:** 484–7.

Haydak, Mykola H. 1949. Causes of deficiency of soybean flour as a pollen substitute for honeybees. JOUR. ECON. ENT. **42:** 573–9.

Haydak, Mykola H. and A. Earl Vivino. 1950. The changes in the thiamine, riboflavin, niacin and pantothenic acid content in the food of female honeybees during growth with a note on the vitamin K activity of royal jelly and beebread. Ann. Ent. Soc. Amer. **43:** 361–7.

House, Howard L. 1948. Nutritional studies with *Blatella germanica* (L.) reared under aseptic conditions. III. Five essential amino acids. Canad. Ent. **81:** 133–9.

Kuiken, K. A. and Carl M. Lyman. 1949. Essential amino acid composition of soy bean meals prepared from twenty strains of soy beans. Jour. Biol. Chem. **177:** 29–36.

Kuiken, K. A., Carl M. Lyman and Fred Hale. 1947. Factors which influence the stability of tryptophan during the hydrolysis of proteins in alkaline solution. Jour. Biol. Chem. **171:** 551–60.

Kuiken, K. A., W. H. Norman, C. M. Lyman, F. Hale and L. Blotter. 1943. The microbiological determination of amino acids. Valine, leucine and isoleucine. Jour. Biol. Chem. **151:** 615–26.

Kuiken, K. A. and P. B. Pearson. 1949. The essential amino acid (except tryptophan) content of colostrum and milk of the cow and ewe. Jour. Nutr. **39:** 167–76.

Lyman, Carl M. and K. A. Kuiken. 1949. The amino acid composition of meat and some other foods. Tex. Agr. Exp. Sta. Bul. 708.

Lyman, C. M., O. Moseley, B. Butler, S. Woodard and F. Hale. 1946. The microbiological determination of amino acids. III. Methionine. Jour. Biol. Chem. **166:** 161–71.

Lyman, C. M., K. A. Kuiken and F. Hale. 1947. The histidine content of meat. Jour. Biol. Chem. **171:** 233–45.

Melampy, R. M. and D. B. Jones. 1939. Chemical composition and vitamin content of royal jelly. Proc. Soc. Exp. Biol. Med. **41:** 382–8.

Nelson, J. A., A. P. Sturtevant and Bruce Lineburg. 1924. Growth and feeding of honeybee larvae. U.S.D.A. Dept. Bul. 1222.

Pratt, John J. and Howard L. House. 1949. A qualitative analysis of the amino acids in royal jelly. Science **110:** 9–10.

Riesen, W. H., D. R. Clandinin, C. A. Elvehjem and W. W. Cravens. 1947. Liberation of essential amino acids from raw, properly heated, and overheated soy bean oil meal. Jour. Biol. Chem. **167:** 143–50.

Sarkar, R. C., S. H. Wittwer, R. W. Lueke and H. M. Sell. 1949. Quantitative estimation of some amino acids in sweet corn pollen. Arch. Biochem. **22:** 353–6.

Schaefer, C. W. and C. L. Farrar. 1946. The use of pollen traps and pollen supplements in developing honeybee colonies. U.S.D.A., B.E.P.Q. **E-531.**

Todd, F. E. and O. J. Bretherick. 1942. The composition of pollens. JOUR. ECON. ENT. **35:** 312–6.

Townsend, G. F. and C. C. Lucas. 1940. The chemical nature of royal jelly. Biochem. Jour. **34:** 1155–62.

Vivino, E. A. and L. S. Palmer. 1944. The chemical composition and nutritional value of pollens collected by bees. Arch. Biochem. **4:** 129–36.

Wilson, L. P. 1941. The influence of L-proline on larval growth in *Drosophila melanogaster.* Growth **5:** 11–8.

Wilson, L. P. 1945a. Tolerance of larvae of *Drosophila* for amino acids: tryptophan. Growth **9:** 145–54.

Wilson, L. P. 1945b. Tolerance of larvae of *Drosophila* for amino acids: tyrosine, phenylalanine, alanine. Growth **9:** 341–52.

Wilson, L. P. 1946. Tolerance of larvae of *Drosophila* for amino acids: methionine, cystine, cysteine. Growth **10:** 361–74.

Wilson, L. P. and M. M. Birch. 1944. Tolerance of larvae of *Drosophila* for amino acids: arginine. Growth **8:** 125–48.

Woolley, D. W. 1948. Discovery, purification, and chemical properties of strepogenin. VIII. Congr. chim. biol. **1:** 101–13.

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Time Factors in Mating Systems for Honey Bees[1]

MARTIN S. POLHEMUS and O. W. PARK,[2] *Iowa State College, Ames*

Artificial insemination of honey bees has only recently made possible the development of inbred lines of bees for study and observation. The expected consequences of inbreeding under various regular mating systems in diploid animals were clarified by Sewall Wright in 1921. However, honey bee pedigrees are not comparable to those of diploid animals because of the haploid genetic constitution of the drone or male bee. Some of the genetic implications of this situation have been discussed by Kalmus and Smith (1948), Polhemus *et al.* (1950), and Crow & Roberts (1950).

It was pointed out, at least as long ago as 1915 by Newell, that the drone bee can be considered simply a random gamete from his female parent, but with the power of reduplication. Genetically, the gametes he produces are exact replicates of the gamete which he himself is. Consequently, the genetic situation can be depicted accurately in pedigrees by showing only the females as individuals, the males being indicated merely as gametes. The rather unusual result is all-female pedigrees, such as we see in figure 1, depicting regular mother-daughter mating in honey bees. The apparent physical pairing is between a brother and a sister. Both are offspring of the same queen, and considering the drone as a gamete results in the genetic pairing of this daughter queen with her mother. Such matings are repeated regularly in this system.

Pedigrees constructed in this manner are comparable to those of ordinary diploid organisms, provided no drone has more than one daughter in the pedigree. Computation of inbreeding coefficients and relationships is thus greatly simplified, being done according to the same rules as for diploid organisms.

In full-sister matings with honey bees, depicted in figure 2, and in certain other systems, more than one daughter must be reared from each drone in the pedigree. Both these daughters will receive identical gametes from him, unlike the usual diploid situation in which the male gives each of his daughters an independent and randon-sample half of his own genes. Because the haploid nature of the drone eliminates Mendelian segregation and sampling in the production of gametes by him, the relationship between two full-sister queens will be 75 per cent, instead of the usual 50 per cent for full sisters in diploid animals. No analogy can be found in diploid animals for honey bee mating systems of this type, and all relationships and inbreeding coefficients in such pedigrees must be re-computed to compensate for this higher relationship. The use of multiple-drone inseminations under such mating systems may considerably complicate such calculations.

The rapidity with which inbreeding progresses under various regular mating systems is of primary importance to bee breeders who are attempting to develop pure lines or hybrids. It is customary to compare the relative efficiency of various regular inbreeding systems on the basis of heterozygosity lost per generation. Figure 3 illustrates graphically the heterozygosity lost—we might call it the per cent of inbreeding—per generation under five regular inbreeding systems in honey bees. Self-fertilization, in which the unmated queen is stimulated to lay unfertilized eggs and then mated to her own drone offspring, results in the most rapid approach to homozygosity per generation. Under this system, half of the remaining heterozygosity is lost with each succeeding generation. This is followed in order of decreasing efficiency by full-sister mating, mother-daughter mating, aunt-niece mating, and mating the offspring back to the older parent.

In honey bees, the actual rapidity (in days) with which certain levels of inbreeding may be attained depends nearly as much on the time requirements for each generation as on the heterozygosity lost *per generation*. The elapsed time from queen to daughter through the ovum is approximately 30 days, as compared with

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[2] The authors wish to express grateful acknowledgment to Dr. Jay L. Lush, professor of animal breeding, Iowa State College, for helpful suggestions and critical reading of the manuscript.

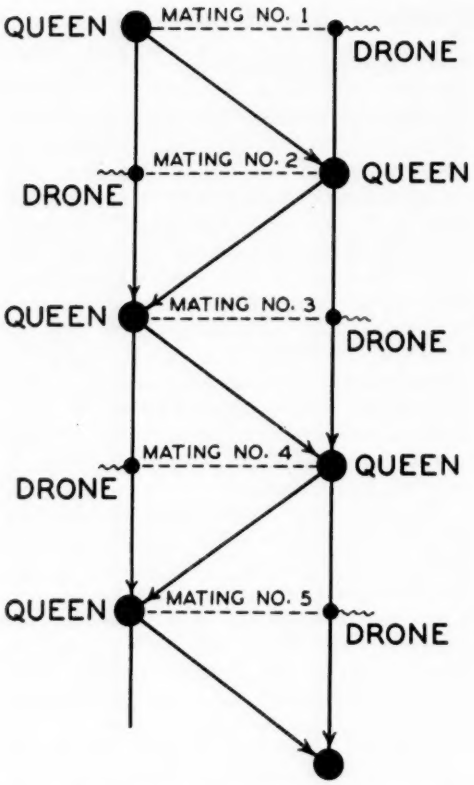

FIG. 1.—Mother-daughter mating in honey bees. The physical pairing is between brother and sister.

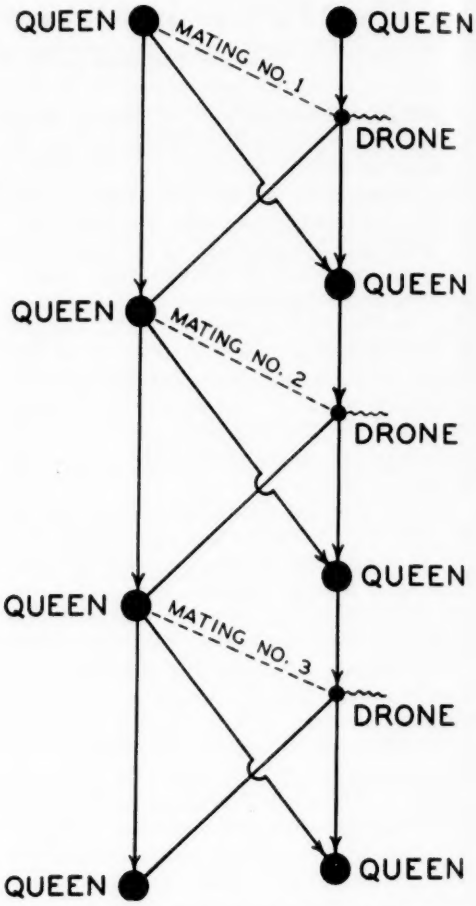

FIG. 2.—Full-sister mating in honey bees. The physical pairing is between aunt and nephew.

something like 70 days, or even more, from queen to daughter through the drone. Under the mating system illustrated in figure 2, a drone must be produced from each female generation to be used in producing the next generation. Consequently, the average time required in practice for each new female generation is over 70 days. The mother-daughter system, by contrast, requires only 48 days

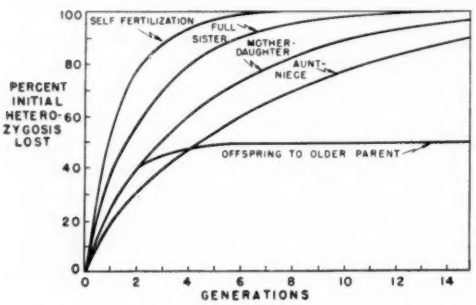

FIG. 3.—Loss of heterozygosis per generation under various regular inbreeding systems in honey bees.

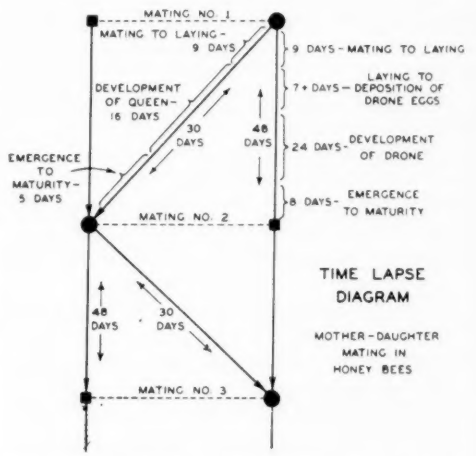
MATING NO. 1
MATING TO LAYING - 9 DAYS
9 DAYS - MATING TO LAYING
DEVELOPMENT OF QUEEN - 16 DAYS
7+ DAYS - LAYING TO DEPOSITION OF DRONE EGGS
30 DAYS
48 DAYS
24 DAYS - DEVELOPMENT OF DRONE
EMERGENCE TO MATURITY - 5 DAYS
8 DAYS - EMERGENCE TO MATURITY
MATING NO. 2
TIME LAPSE DIAGRAM
MOTHER-DAUGHTER MATING IN HONEY BEES
48 DAYS
30 DAYS
MATING NO. 3

FIG. 4.—Approximate time required, step by step, for rearing queens and drones under a regular mother-daughter inbreeding system in honey bees.

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for the production of each new female generation. This may be speeded up even more by stimulating every second queen with carbon dioxide without waiting to mate her. This should result in production of unfertilized eggs 9 days before she is to be mated, thus starting the next generation of drones through their developmental cycle much sooner than would otherwise be the case. The resulting time lapses are 48, then 30, then 48, then 30 days per generation, and so on, permitting nine and one sixth generations per year.

A mating-system diagram is broken down in figure 4 to show the time involved in each step. Drones are shown as individuals for the sake of clarity. In determining the time involved between any two successive matings, one must always follow "the line of most resistance," as each mating interval can be no shorter than the time required for the slowest individual to develop (unless special technique is employed to gain time by overlapping certain generations). In this case, the limiting factor is drone development which requires 48 days in each generation. The grandmother-granddaughter system, set up with the thought in mind of rearing two generations of queens from one female before her drones are needed, results in the production of a new generation about every 30 days.

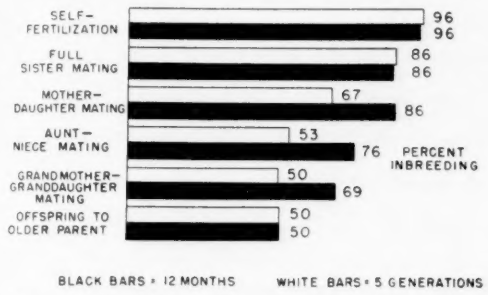

FIG. 5.—Comparison of per-generation efficiency with per-unit-time efficiency for several regular inbreeding systems in honey bees.

Differences in time required for a generation under various systems have a marked effect on the actual efficiency of such systems, as shown in figure 5. The open bars show the inbreeding attained in *five generations* under each of the various systems, while the solid bars show the inbreeding attained in *12 months* under the same systems. This basis for comparison was chosen since both self-fertilization and regular full-sister mating require almost exactly 12 months for five female generations. The mother-daughter and aunt-niece systems, which rank far below the top in efficiency per generation, show a marked increase in relative efficiency when considered on a per-unit-time basis, because of their short generation intervals. A gain of nearly 20 per cent in a year's time is realized under the mother-daughter system if the time factor is considered. As a result, one can progress just as far with that system as with the second in 12 month's time, despite the considerably greater inbreeding for *each generation* under full-sister mating. This gain assumes considerable practical importance when it is remembered that the inbreeding rate is lowered by an unknown amount under the full-sister plan if more than one drone is used to fertilize each queen, and that single-drone inseminations at present are impractical if sustained performance of the queen is desired. As a consequence, a breeder who might be tempted to utilize the full-sister mating system because of its effectiveness per generation will probably find it more advantageous to obtain a comparable level of inbreeding in 12 months with the mother-daughter system while employing the more practical multiple-drone inseminations. Such inseminations do not change the rate of inbreeding in the mother-daughter system since only one drone is the sire of the daughter chosen to continue the line, no matter how many drones were used for inseminating the mother. Other similar situations may arise in which such considerations may make possible the acceptance or utilization of a mating system which would otherwise be discarded in favor of those with a somewhat fictitious advantage.

From a practical standpoint, the sys-

Table 1.—Generations and homozygosity obtainable in 12 months under various regular inbreeding systems in honey bees.

SYSTEM	PHYSICAL MATING	GENERATIONS	HOMOZYGOSITY
1. Self-fertilization	Unfertilized queen to her son	4.875	96%
2. Full sister	Aunt-nephew	4.875	86%
3. Mother-daughter	Brother-sister	9.0625	86%
4. Aunt-niece	First cousins	9.75	70%
5. Grandmother-granddaughter	Maternal uncle to his niece	12	69%
6. Offspring to older parent	Successive queens to drones from one queen	12	50%

tems permitting many generations per year may require considerably more work in rearing queens and drones, and in performing the inseminations. Such systems cannot compare favorably as tools for rapid inbreeding unless they permit results equalling or surpassing those obtainable under self-fertilization or full-sister mating in a given time. This of course does not preclude their usefulness for certain other purposes, such as concentrating a line around a single individual, the goal of offspring-to-older-parent matings.

A summary of the effects of generation-interval differences on the rate of inbreeding in six different honey bee mating systems is given in table 1. The last column indicates the per cent inbreeding possible in 1 year under each system, if each mating is accomplished in the least possible time. Nearly 2.5 months are required for each generation under the first two systems, permitting only four and seven eights generations per year. In contrast, the last two systems provide a new female generation regularly once a month, or 12 generations a year—more than twice the number possible under either of the first two systems. It is evident that the generation interval should be considered in evaluating any breeding plan pertaining to honey bees.

LITERATURE CITED

Crow, James F., and William C. Roberts. 1950. Inbreeding and homozygosis in bees. Genetics **35:** 612–21.

Kalmus, H., and C. A. B. Smith. 1948. Production of pure lines in bees. Jour. Genetics **49:** 153–8.

Newell, Wilmon. 1915. Inheritance in the honey bee. Science **41:** 218–9.

Polhemus, Martin S., Jay L. Lush, and Walter C. Rothenbuhler. 1950. Mating systems in honey bees. Jour. Heredity **41:** 151–5.

Wright, Sewall. 1921. Systems of mating. Genetics **6:** 111–78.

Control of *Petrobia latens* in the Imperial Valley of California[1]

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In January, 1950, a species of mite, *Petrobia latens* (Müller), caused extensive damage to carrots in the Imperial Valley of California. This mite has been known for a number of years as a pest of economic importance, primarily on wheat and other grass-like plants. Jones & Mecom (1935) were first to report that this species caused considerable damage to onions in Texas. McGregor (1950) listed this species as occurring on wheat, barley, grass, ryegrass, *Iris*, gladiolus, sorghum, alfalfa, burclover, moss, and wild onion, as well as in houses. In 1950 *P. latens* was found to be damaging carrots, onions, and cantaloupes in the Imperial Valley of California. In all probability it has been in this area for some time, because similar damage to these crops occurred in 1948 and 1949.

Injury to carrot fields usually starts in small, localized areas and then spreads rapidly through the fields. The foliage turns yellow in the early stages of infestation and soon becomes dry and brittle. Examination of the affected foliage revealed great numbers of this relatively large, active mite. No webbing was observed on the plants. When disturbed, the mites run rapidly over the leaf surface or drop to the ground.

Jones & Mecom (1935) reported that sulfur gave good control of this mite on onions. In the Imperial Valley, commercial applications of sulfur were applied to affected carrot fields in January, 1950, but probably because of cold weather, poor control was obtained. In the present experiments the following recently developed acaricides were tested for effectiveness as dusts:

p-Chlorophenyl phenylsulfone (compound R-242),[2] 5 and 10 per cent

2-(*p-tert*-Butylphenoxy) isopropyl 2-chloroethyl sulfite (compound 88R),[3] 5 per cent

[1] Paper No. 684, University of California Citrus Experiment Station, Riverside, California.

[2] *Sulphenone*, Stauffer Chemical Company.

[3] *Aramite*, Naugatuck Chemical Division of the U. S. Rubber Company.

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p-Chlorophenyl-*p*-chlorobenzenesulfonate (compound K-6451),[4] 10 per cent
2,4-Dichlorophenylbenzenesulfonate (compound 923),[5] 10 per cent
0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate (compound 3901),[6] 1 per cent
Ethyl-*p*-nitrophenyl thionobenzenephosphonate (EPN),[7] 1 and 2 per cent
Parathion,[6] 1 per cent

Parathion (1 per cent) was used alone and with sulfur (85 per cent). Sulfur was also used alone.

EL CENTRO EXPERIMENT.—On February 14, 1950, the various acaricides were applied as dusts to a carrot field in the El Centro area. There were two rows of carrots 12 inches apart in each bed, and the beds were 42 inches apart from center to center. Each treatment was replicated six times, and each replicate was two beds wide and 62 feet long. A single application was made by a rotary hand duster at 33 to 41 pounds of material per acre. The nozzle was directed toward one row of carrots at a time. Maximum daytime temperatures at the time of this experiment ranged from about 85° to 90° F.

Mites were sampled and counted in the field. The tendency for the mites to fall off, or to be knocked off the plants easily was utilized in making the counts. A sheet of stiff white cardboard 12 by 16 inches in size was used for this purpose, and lines were drawn across it at 2.5-inch intervals, so as to form sections 2.5 inches wide and 12 inches long. The cardboard was inserted under the foliage up to the base of the plants with the sections perpendicular to the carrot row. The carrot foliage above the cardboard was then struck sharply three times, with one hand, over and against the cardboard. In this fashion practically all the mites were knocked onto the cardboard; those in the 2.5-inch-wide section underneath the hand were then counted. Three samples were taken in each replicate, to make a total of 18 samples per treatment. Counts were made on February 21 (7 days after treatment) and again on March 2 (16 days after treatment). Further counts could not be made because the grower treated his entire field with an airplane application of sulfur. The materials and the results obtained are summarized in table 1.

In this experiment parathion, parathion plus sulfur, 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate, and sulfur gave excellent mite reductions (94.9 to 98.4 per cent) in 7 days. At the end of 16 days, these materials were maintaining mite control, although parathion appeared to be losing its effectiveness somewhat. In 7 days, 2,4-dichlorophenylbenzenesulfonate gave a poor reduction in mite population (51.4 per cent), but at the end of 16 days the reduction was excellent (94.7 per cent). The compound *p*-chlorophenyl-*p*-chlorobenzenesulfonate, a slow-acting material, gave 79.7 per cent control at the end of 16 days, and probably would have shown better results if further counts could have been made. At the dosage used in this test, *p*-chlorophenyl phenylsulfone gave only fair control (63.4 per cent), and both 1 and 2 per cent ethyl-*p*-nitrophenyl thionobenzenephosphonate gave poor control. At the end of 16 days, 2-(*p-tert.*-butylphenoxy) isopropyl 2-chloroethyl sulfite gave 44.5 per cent control. Because it was found that this particular batch of this compound was of inferior quality, the results of this treatment are not shown in the table. The sulfur-treated plants appeared to recover their normal dark-green appearance a little more quickly than plants given the other treatments.

HEBER EXPERIMENT.—In this test the materials were applied as dusts, on March 31, to a carrot field in the Heber area of the Imperial Valley. A single application was made by rotary hand duster at 34 to 45 pounds of material per acre. There were two rows of carrots 12 inches apart in each bed, and the beds were 42 inches apart from center to center. Each replicate was one bed wide and 50 feet long, and each treatment was replicated three times. Because of variations in the mite populations, two untreated carrot beds were left between the treated beds. It was therefore possible to obtain a mite population count in an untreated area adjacent to each treated area. At the time of this experiment, the maximum daytime temperatures ranged from about 95° to more than 100° F.

Sampling was accomplished in the same manner as in the previous experiment. Three samples per plot were taken for a total of nine samples per treatment. Counts were made on April 4 (4 days

[4] *Ovotran*, Dow Chemical Company.
[5] *Genitol 923*, General Chemical Company.
[6] American Cyanamid Company.
[7] *EPN-300 Insecticide*, E. I. du Pont de Nemours and Company, Inc.

Table 1.—Effect of various acaricide dusts applied for control of *Petrobia latens* on carrots near El Centro, California. Treated February 14, 1950.

Treatment[1]	Dosage, Pounds per Acre	Mites			
		February 21		March 2	
		Number	Per Cent Reduction (Compared with Check)	Number	Per Cent Reduction (Compared with Check)
Parathion, 1%	33	14	96.7	32	85.9
Parathion, 1%, + sulfur, 85%	41	7	98.4	9	96.0
Sulfur	41	22	94.9	26	88.6
2,4-Dichlorophenylbenzenesulfonate, 10%	41	208	51.4	12	94.7
0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate, 1%	37	21	95.1	13	94.3
p-Chlorophenyl-*p*-chlorobenzenesulfonate, 10%	33	105	75.5	46	79.7
p-Chlorophenyl phenylsulfone, 5%	33	145	66.1	83	63.4
Ethyl-*p*-nitrophenyl thionobenzenephosphonate, 1%	33	151	64.7	128	43.6
Ethyl-*p*-nitrophenyl thionobenzenephosphonate, 2%	33	123	71.3	152	33.0
Check	—	428	—	227	—

[1] All dusts except that of *p*-chlorophenyl phenylsulfone, which was a commercial mixture, were made from wettable powders, with pyrophyllite as a diluent.

after treatment) and on April 13 (13 days after treatment). The materials used and the results obtained are summarized in table 2.

In this experiment, parathion and parathion plus sulfur gave almost perfect control at the end of 4 days (98.2 and 97.2 per cent, respectively). Sulfur gave excellent control at this time (94 per cent). The dosage of *p*-chlorophenyl phenylsulfone was increased after the El Centro experiment from 5 to 10 per cent, and at the end of 4 days it had reduced the mite population by 89.4 per cent, compared with checks. Results with 2,4-dichlorophenylbenzenesulfonate were also good at this time, showing 82.7 per cent control. The compounds *p*-chlorophenyl-*p*-chlorobenzenesulfonate and ethyl-*p*-nitrophenyl thionobenzenephosphonate gave poor control at the end of 4 days, but when the second count was made on April 13, very few mites were found on either the treated or the untreated carrot plants, except in the areas treated with the latter compound. Large numbers of predators

Table 2.—Effect of various acaricide dusts applied for control of *Petrobia Latens* on carrots near Heber, California. Treatment March 31, 1950.

Treatment[1]	Dosage, Pounds per Acre	Mites				
		April 4			April 13	
		Number			Number	
		Treated Plots	Untreated Plots	Per Cent Reduction	Treated Plots	Untreated Plots
Parathion, 1%	40	5	268	98.2	5	5
Parathion, 1%+sulfur, 85%	45	6	260	97.2	1	12
Sulfur	45	27	450	94.0	1	3
p-Chlorophenyl phenylsulfone, 10%	45	33	310	89.4	1	1
2,4-Dichlorophenylbenzenesulfonate, 10%	45	28	162	82.7	1	1
p-Chlorophenyl-*p*-chlorobenzenesulfonate, 10%	34	136	232	41.4	2	1
Ethyl-*p*-nitrophenyl thionobenzenephosphonate, 2%	45	306	424	27.8	178	27

[1] All dusts except that of *p*-chlorophenyl phenylsulfone, which was a commercial mixture, were made from wettable powders, with pyrophyllite as a diluent.

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(*Triphleps* sp. and *Geocoris* sp.) were found in the field at the time of the second count and probably were responsible for the reduction in mite population. The high count in the areas treated with ethyl-*p*-nitrophenyl thionobenzenephosphonate may have resulted from the fact that this material repelled or killed the predators while it failed to control the mites.

COMMERCIAL APPLICATIONS.—Sulfur dust applied during warm weather by commercial operators using either air or ground equipment and a dosage of about 50 pounds per acre gave excellent mite control. However, during cool weather sulfur alone was inadequate. Commercial applications of parathion dust at the time of these experiments were not permitted in the Imperial Valley, so in this area during cool weather parathion sprays were used effectively. Two pounds of the 25 per cent wettable parathion powder plus a wetting agent were applied as a spray in 100 gallons of water per acre. The most effective equipment was a ground sprayer equipped with a modified weed-oiling boom having four nozzles per row of carrots, or eight nozzles per bed. It operated at 125 pounds pressure per square inch and sprayed six beds at a time. Most of the parathion-sprayed fields were retreated 5 to 7 days later with an application of dusting sulfur at 40 to 50 pounds per acre. This treatment following the parathion spray practically eliminated the mite population.

Several other commercial treatments in the spring of 1950 gave varying degrees of success. A 1 per cent tetraethyl pyrophosphate dust used at a dosage of 40 pounds per acre and applied at night with a ground duster gave very little reduction in the mite population, and 1 pint of 20 per cent tetraethyl pyrophosphate in 50 gallons of water per acre gave poor control. A commercial application of a light-medium oil spray gave no control.

SUMMARY.—Two experiments with acaricide dusts for control of *Petrobia latens* (Müller) on carrots were conducted in two different areas in the Imperial Valley of California. In these tests, single applications were made by rotary hand duster at 33 to 45 pounds per acre. One per cent parathion plus 85 per cent sulfur, 1 per cent 0,0-dimethyl-S-(2-oxo-ureido-ethyl)-dithiophosphate, sulfur, and 1 per cent parathion gave 94 to 98 per cent control within 7 days after treatment. These materials maintained excellent mite control, but 16 days after treatment parathion appeared to be losing its effectiveness. At temperatures ranging from 95° to more than 100° F., 10 per cent *p*-chlorophenyl phenylsulfone and 10 per cent 2,4-dichlorophenylbenzenesulfonate gave, respectively, 89 and 83 per cent control in 4 days. At lower temperatures (85° to 90° F.), they gave excellent control, but were slower in action. Five per cent *p*-chlorophenyl phenylsulfone was tested, but at this dosage it gave only fair control. Ten per cent *p*-chlorophenyl-*p*-chlorobenzenesulfonate, a very slow-acting material, gave 80 per cent control at the end of 16 days, but only 41 per cent control in 4 days. In both experiments ethyl-*p*-nitrophenyl thionobenzenephosphonate (1 and 2 per cent) gave poor control.

LITERATURE CITED

Jones, S. E. and W. H. Mecom. 1935. *Petrobia tritici* (Ewing) on onions and its control. JOUR. ECON. ENT. **28**: 650.

McGregor, E. A. 1950. Mites of the family Tetranychidae. Amer. Midland Nat. **44**(2): 257–420.

DDT Spray Formulations for Control of White-Fringed Beetles

IRVING KEISER and CHAS. F. HENDERSON,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

DDT was shown by Young (1944) to be the most effective insecticide ever tested against white-fringed beetles, *Graphognathus* spp. Studies were undertaken to determine how best to use this insecticide in field operations. This paper deals with a portion of the tests developing DDT spray formulations for controlling the adult beetle.

Studies were conducted in 1945 at Long Beach, Mississippi, to determine the effect of various solvents in DDT emulsion and solution sprays on the foliage and on subsequent crop yield. One rather highly volatile proprietary petroleum solvent[2] was least injurious to the plant foliage and resulted in the highest DDT residues on cotton foliage analyzed for hydrolyzable chlorine by the method of Gunther (1945). This product evaporated three times as rapidly as xylene. Xylene was second in both these advantages and was selected for use in DDT-emulsion-spray studies because of cost, availability from numerous sources, and other reasons.

COMPARATIVE ADHESIVENESS OF DDT SPRAYS ON FOLIAGE.—Studies were conducted in 1946 at Long Beach, Mississippi, where emulsion and suspension sprays were applied at 5 and 10 pounds of DDT per acre, in a field of Mexican clover (*Richardia scabra* L.), a weed native to this area. Five quarts of xylene were used with the 5-pound dosage and 10 quarts with the 10-pound dosage of DDT in the emulsion sprays. A 50 per cent wettable powder was used in the suspension sprays. Both emulsions and suspensions were applied at 6 gallons of spray per acre, with a concentrated-spray machine developed by the Bureau. Foliage samples were collected for determining initial deposits, and again on four dates, after varying amounts of weathering. These were analyzed by the method of Umhoefer (1943). There were 8 days between the first and second samplings, and 10, 22, and 37 days between the respective subsequent samplings. Not only were the two emulsions more adhesive than the suspensions, but the 10-pound dosage was better than the 5-pound dosage of the same formulation (Fig. 1). The 10-pound emulsion showed the highest percentage of DDT foliage residues. The same quantities of DDT and solvent were contained in 3 gallons of spray for the 10-pound treatment as in 6 gallons for the 5-pound treatment. Better weathering appeared to be associated with the more concentrated emulsion sprays.

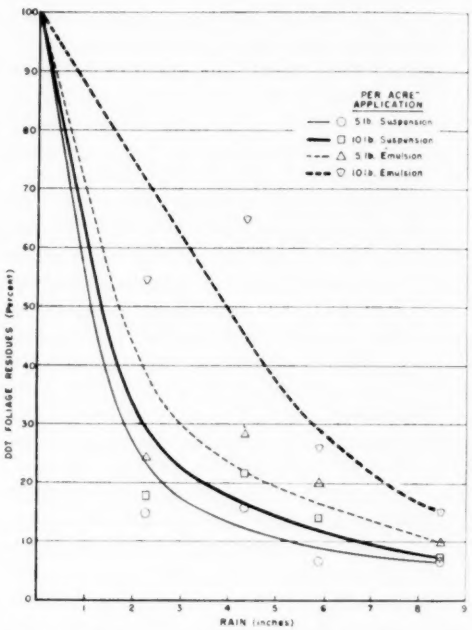

FIG. 1.—Comparative adhesiveness of DDT emulsion and suspension sprays on Mexican clover.

In another experiment in 1946 at Long Beach, a comparison was made of emulsion and suspension sprays applied to cultivated plants grown in the field. Soybeans and field peas were planted especially for these tests. A poor stand was obtained because of unfavorable weather conditions, and there were insufficient pea plants to test emulsion spray. Applications were made with the concentrated spray

[1] Acknowledgment is made to William Breland and J. M Allen, who assisted in the 1946 foliage-spray tests, the 1947 crystal-pattern tests, and the 1947 and 1948 field mortality counts. E. R. Millet and R. E. Warner also assisted in the 1947 and 1948 counts.

[2] Amsco Solv A.

machine. Foliage samples were collected for determining initial deposits and again 1 and 3 weeks later. During the first week there was no rain, but the following week 0.40 inch of rain fell. A week after the third collection the plants were in such poor shape that no further sampling was possible. Figure 2 presents the comparative adhesiveness of the DDT sprays.

DDT emulsion and suspension sprays on soybeans at each dosage level resulted in approximately the same residues from natural weathering with no rainfall, as noted by the p.p.m. figures 1 week after treatment (Fig. 3). It was only after rain that the superior adhesiveness of emulsion sprays on soybeans was manifested. At each dosage the emulsions were more adhesive than suspensions on soybeans after the rain. A similar comparison was

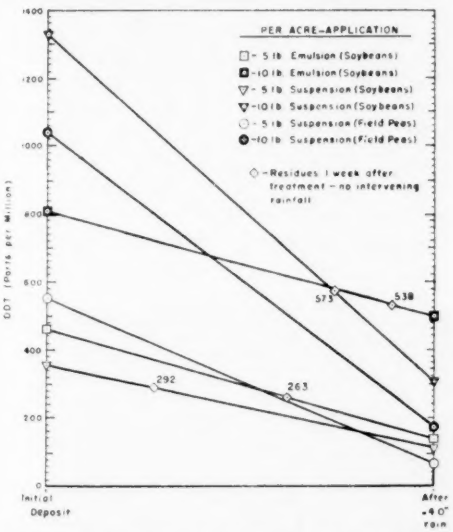

FIG. 2.—Comparative adhesiveness of DDT emulsion and suspension sprays on soybeans, and of DDT suspension sprays on soybeans and field peas.

not possible with field peas, as owing to scarcity of available plants only suspension spray was tested.

Moreover, the field peas were not sampled after 1 week without rainfall. However, it may be noted from figure 3 that the field peas showed greater washoff from suspension sprays than did soybeans, as the leaves are smoother and less likely to retain the deposits. Again the 10-pound emulsion resulted in the highest DDT foliage residues of the four sprays tested on soybeans.

Studies of DDT residues in the soil

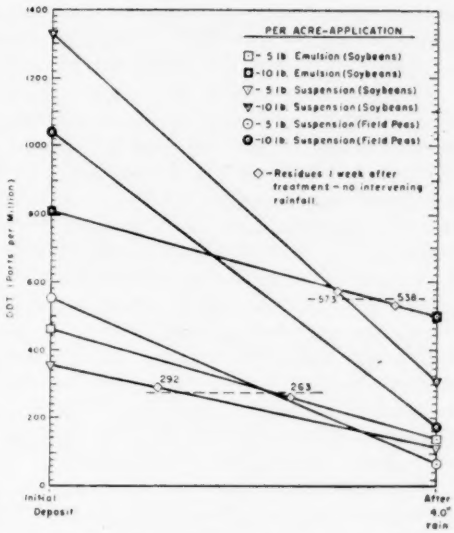

FIG. 3.—Comparative adhesiveness of DDT emulsion and suspension sprays on soybeans and field peas.

over a period of years will be reported at a later date. It has been noted, however, that the percentage recovered is almost the same regardless of the amount originally applied. For example, if 50 pounds of DDT per acre is recovered after a given time from a 100-pound soil treatment, approximately 25 pounds is recovered from a 50-pound, and 12.5 pounds from a 25-pound treatment. The difference in recoveries from the 5 and 10 pound per acre emulsion sprays on Mexican clover and soybeans in the 1946 tests suggests better weathering of the more concentrated sprays.

Emulsion sprays were selected for use in field operations against adult white-fringed beetles on the basis of the 1946 foliage adhesive studies. Since it appeared that better DDT residues were associated with the more concentrated sprays, additional tests were made late in the summer of 1947 to improve the DDT-xylene emulsion spray formulation. Different volumes of total spray were tested to determine whether or not concentration would affect the volatilization of the xylene, affect the crystal pattern, and result in DDT deposits with better weathering qualities. Adult beetle mortalities in the field and chemical analyses of the sprayed foliage were to be used as the criteria of effectiveness. Two solution sprays were included in the crystal

pattern tests, and two solution and suspension sprays in the mortality and analytical tests for comparative purposes.

CRYSTAL-PATTERN STUDIES.—These were conducted in an enclosed airplane hangar at the Army Air Field, Gulfport, Mississippi. Various DDT emulsions and solutions were applied with the concentrated spray machine. Applications were made at the rate of 1 pound of DDT in 2, 6, and 12 gallons per acre to glass plates 2.75 inches square onto some of which were glued[1] paper toweling strips cut to the same dimensions. The treated strips were analyzed to determine the amount of DDT recovered, and the bare glass slides were examined under the microscope for DDT crystal pattern.

The chemical analyses showed that approximately equal amounts of DDT were recovered from each dosage. Evidently the actual volume of spray was not a factor in obtaining adequate deposit and distribution of the DDT at the volumes tested and under the conditions of this experiment.

The crystals deposited from emulsions containing 1 quart of xylene applied at 2 gallons per acre were compact, with some short, fine, reticulated needles; those from emulsions applied at 6 gallons were globose, with longer needles emanating from a central core; and those from the emulsions applied at 12 gallons per acre were composed entirely of long needles (Fig. 4). The retarded rate of evaporation as the amount of water in the spray increased permitted the crystals to become larger.

The crystals deposited from emulsions containing 5 quarts of xylene and applied at 6 gallons per acre were globular and larger than those formed from smaller amounts of xylene. It had been expected that an increased amount of solvent might result in better deposit and distribution of the insecticide, but this was not found to be so.

The crystals deposited from a solution of DDT in xylene and summer oil and from a kerosene solution were all long needles, those from the summer oil solution being the longest (Fig. 5).

A supplementary study was made to determine the relative size of the droplets deposited from the sprays applied at 2, 6, 12 gallons per acre. Potassium permanganate dissolved in water was used as the spray material. The spray was collected on glass plates, and the potassium permanganate, which crystallized

[1] With *Tanglefoot*.

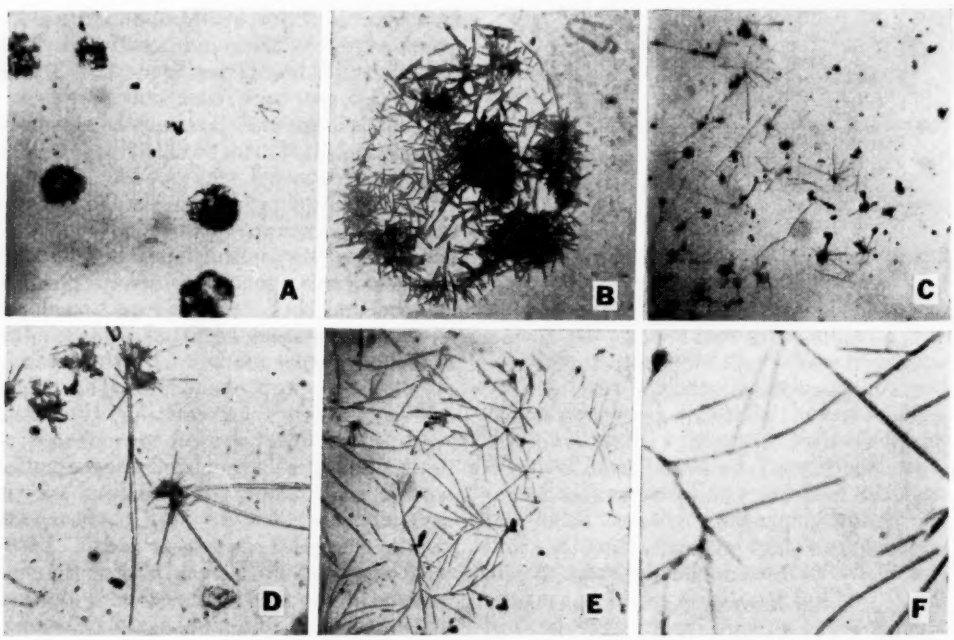

FIG. 4.—DDT crystal patterns from 1 pound of DDT per acre applied in the following quantity of emulsion: *A*, *B*, 2 gallons; *C*, *D*, 6 gallons; *E*, *F*, 12 gallons. (*A*, *C* and *E*, 50×; *B* and *D*, 220×; *F*, 200×.)

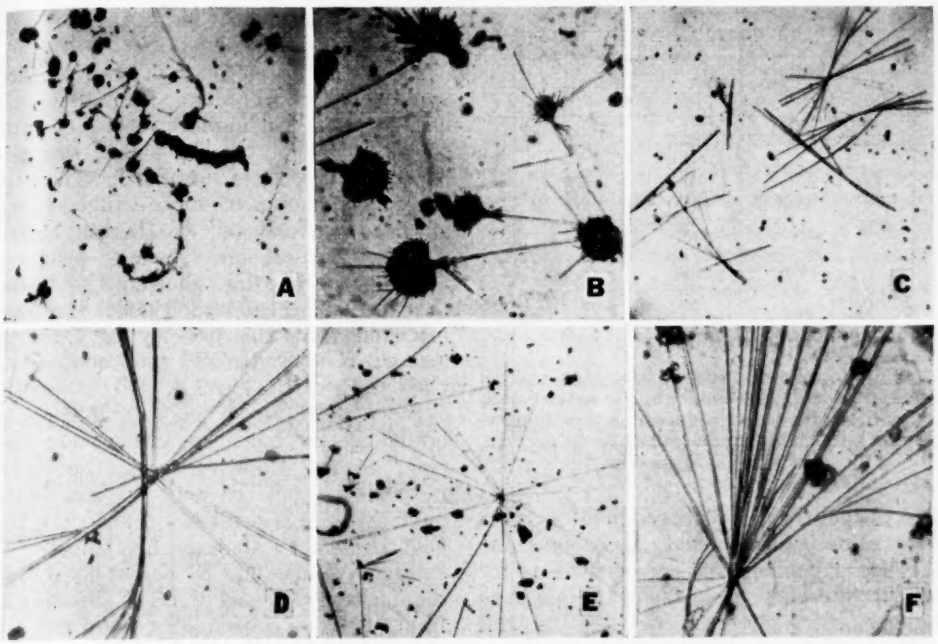

FIG. 5.—DDT crystal patterns from 1 pound of DDT per acre: *A*, *B*, in emulsion containing 5 quarts of xylene, and emulsifier, and water to make 6 gallons; *C*, *D*, in solution containing kerosene to make 2 gallons; and *E*, *F*, in solution containing 0.75 quart of xylene and summer oil to make 2 gallons. (*A*, *C* and *E*, 50×; *B*, *D* and *F*, 220×.)

within the water droplets on drying, afforded an indication of particle size when observed under the microscope. It was noted that the range of droplet size was practically uniform for each concentration of spray, but that the number varied directly with the quantity of total spray. Evidently the gallonage output did not appreciably affect the size of the water droplets, but merely increased their numbers.

In this test the particle size of the spray droplets was apparently affected by the speed of the blower and the diameter of the wind outlet on the nozzle of the concentrated spray machine, rather than by the quantity of spray applied.

FIELD MORTALITY TESTS.—A field experiment was conducted in the late summer of 1947 at Long Beach, Mississippi, to determine the relative effectiveness of various emulsion and solution

Table 1—Comparative effectiveness of DDT sprays against adult white-fringed beetles when applied at the same dosage in various quantities of total spray. Field tests. Long Beach, Mississippi.

FORMULATION (DDT 1 lb. in all sprays)	TOTAL SPRAY GALLONS	MEDIAN PER CENT MORTALITY		RESIDUES ON FOLIAGE AFTER 3 DAYS P.P.M.
		After 3 Days	After 15 Days	
Emulsions:				
Xylene 1 qt. plus *Triton X-100* 1 oz.	2	100	74	144
2 oz.	6	100	70	63
4 oz.	12	100	51	—
Xylene 5 qt. plus *Triton X-100* 2 oz.	6	100	58	71
Suspensions: (50 per cent wettable powder)	2	100	53	—
	6	93	39	—
	12	96	55	—
Solutions:				
Kerosene	2	100	61	45
Summer oil plus xylene 0.75 qt.	2	100	45	65

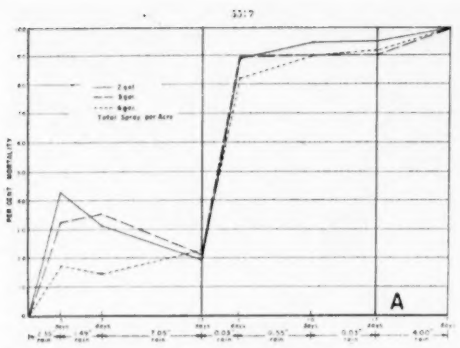

FIG. 6.—Comparative effectiveness of 8 and 16 ounces-per-acre DDT-emulsion sprays against adult white-fringed beetles when applied in three applications at rates of 2, 3, and 6 gallons spray per acre. Long Beach, Mississippi.

sprays against white-fringed beetle adults. The same concentrated spray machine and DDT formulations were used as for the crystal-pattern tests in the airplane hanger. Plots were 0.5 acre in size, and each treatment was triplicated. Three suspension sprays were included for comparative purposes. The median results are shown in table 1.

It will be noted that, of the emulsion sprays, the one applied at 2 gallons per acre showed the highest mortality after 15 days. Evidently the small, compact crystals either were more lethal than the long-needled ones to white-fringed beetle adults or withstood weathering better. The summer-oil spray, which produced the longest needles, showed the lowest mortality. McIntosh (1946), however, reported that the toxicity of DDT to *Tribolium* was directly proportional to the length of the crystal.

Since there was a heavy emergence of adult beetles over the entire test area prior to the 15-day counts, the higher mortality associated with the small compact crystals is probably due to the fact that these crystals were less affected by sunlight. Chisholm & Koblitsky (1947) demonstrated a loss of DDT due to sunlight. The suspension sprays did not give high mortalities 15 days after treatment.

To be effective, the DDT must remain

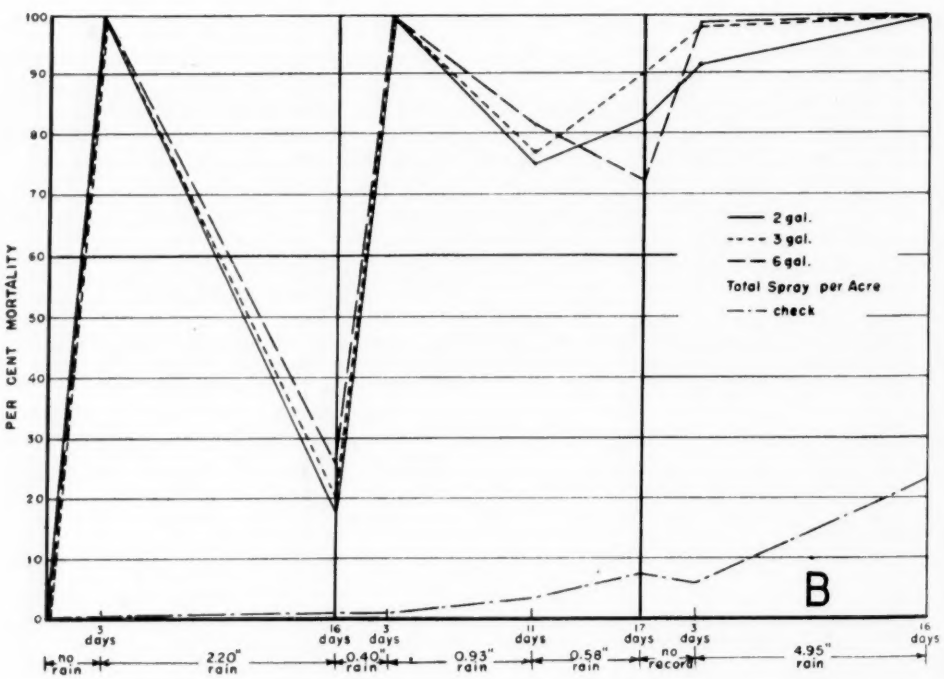

FIG. 7.—Comparative effectiveness of 8-ounce and 1-pound-per-acre DDT-emulsion sprays against adult white-fringed beetles when applied in three applications at rates of 2, 3, and 6 gallons of spray per acre, Wiggins, Mississippi.

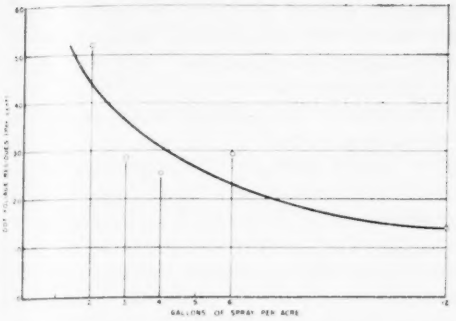

FIG. 8.—Comparative DDT residues from emulsion sprays equivalent to 0.5 pound of DDT in different total volumes. Combined results from 1948 field mortality tests at Long Beach and Wiggins, Mississippi.

on the surface of the leaves, and this retention may best be achieved with the naturally adhesive DDT crystals as deposited from emulsion sprays.

Since the 1947 tests showed that 2 gallons of total spray per acre was at least as good as the 6 gallons previously used in adult white-fringed beetle control operations, 3 gallons were used in 1948. This reduction in dosage resulted in considerable saving in time and labor, as it was necessary to prepare the master spray mixes and refill the spray tanks only half as frequently.

Field mortality tests were also conducted in 1948 at Long Beach and Wiggins, Mississippi, to compare the effectiveness of 0.5- and 1-pound dosages of DDT contained in 2, 3, and 6 gallons of emulsion. At Long Beach the plots were 0.5 acre in size and duplicated. Only individual 0.5-acre plots were available at Wiggins. Three applications were made at approximately 17-day intervals. Adult mortality counts were made 3 days after each treatment and again 1 day before the next application. Whenever possible, additional counts were made between treatments. The results are shown in figures 6 and 7. It is clearly indicated that all three volumes were satisfactory. These tests therefore furnished additional evidence that the more concentrated sprays may be used in control operations.

FOLIAGE RESIDUE TESTS.—Foliage samples were collected after each treatment in the 1948 field mortality tests and also on the day before the next treatment for determination of DDT residues. The results are shown in figure 8. Again it is

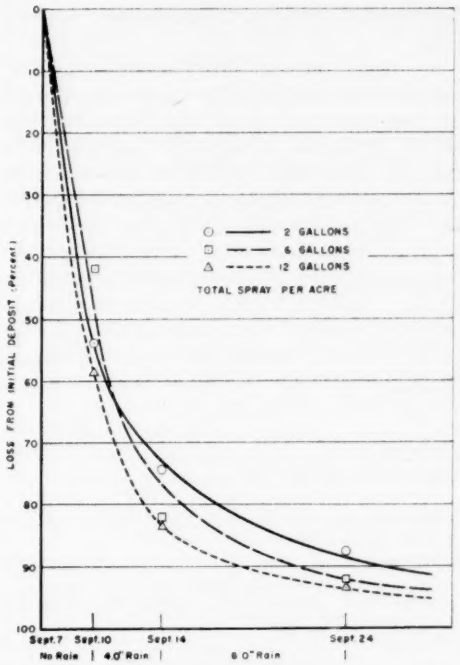

FIG. 9.—Comparative DDT residues from emulsion sprays equivalent to 1 pound of DDT in different total volumes. 1948 foliage residue tests, Long Beach, Mississippi.

noted that the lower dosages gave residues as good as, and probably better than, the less concentrated sprays. An additional test was made late in the summer of 1948 in which DDT was applied at the rate of 1 pound in 2, 6, and 12 gallons of spray per acre to Mexican clover growing in a pecan grove. The results, as noted in figure 9, again indicate that the DDT residues from the 2-gallon sprays are at least as good as those from sprays at the higher gallonages.

It is of interest to note from figure 9 that from 43 to 59 per cent of the DDT applied to the foliage was lost in a 3-day period with no rainfall. Other studies have indicated a heavy loss of DDT applied to foliage when subjected to sunlight, with or without rainfall.

SUMMARY.—In 1946 studies were conducted to compare the adhesiveness of DDT emulsion and suspension sprays applied to foliage in the field with a concentrated spray machine. Emulsion sprays were more adhesive (or weathered better) than suspensions. Higher mortalities of white-fringed beetle adults were associated with higher DDT residues, as dem-

onstrated in 1947 at Long Beach, Mississippi.

In 1947 various DDT emulsions and solutions were applied to glass plates with the concentrated spray machine, and the DDT crystals deposited thereon were studied. The small globular crystals were associated with highly concentrated sprays and rapid evaporation. The long-needled crystals were associated with slower drying sprays, either emulsions with a quick-drying solvent plus a comparatively large amount of water, or solutions containing slower drying solvents. The small globular crystals did not weather to as great an extent as the long-needled ones, as shown by the white-fringed beetle adult mortalities and the chemical analyses of foliage.

In 1948 it was found that emulsions containing 8 and 16 ounces of DDT in 2, 3, and 6 gallons of spray were about equally effective, and that higher DDT residues were associated with the more concentrated sprays. On the basis of these studies, it was possible to reduce the total volume applied in control operations against white-fringed beetle adults, and thereby afford a saving without impairing the effectiveness of the spray.

LITERATURE CITED

Chisholm, R. D., and L. Koblitsky, 1947. Effect of light on DDT residues. Agr. Chem. **2**(9): 35–7.

Gunther, F. A. 1945. Quantitative estimation of DDT and of DDT spray or dust deposits. Indus. and Engin. Chem., Analyt. Ed. **17**: 145–50.

McIntosh, Andrew H. 1946. Relation of crystal size and shape to contact toxicity of DDT suspensions Nature **158**: 417.

Umhoefer, R. R. 1943. Determination of halogens in organic compounds. Indus. and Engin. Chem., Analyt. Ed. **15**: 383–4.

Young, H. C. 1944. DDT against the white-fringed beetle and velvetbean caterpiller. JOUR. ECON. ENT. **37**: 145–7.

Chemical Control of Sweetpotato Insects in Hawaii[1]

MARTIN SHERMAN,[2] *University of Hawaii, College of Agriculture, Agricultural Experiment Station, Honolulu*

The sweetpotato vine borer, *Omphisa anastomosalis* (Guen.), the West Indian sweetpotato weevil, *Euscepes postfasciatus* (Fairm.), and the sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), are the most injurious insects attacking the sweetpotato in Hawaii. The vine borer is a pyralid moth which spends its destructive stage as a larva feeding within the stem. The two species of weevils have similar habits and can be injurious as adults feeding on the stems or potatoes, or particularly as larvae within the stems and potatoes. The use of arsenicals or cryolite in combination with good cultural and sanitary practices has been moderately successful in controlling these insects (Holdaway 1941; Tucker 1937).

The potency of the insecticides now available suggests the possibility of obtaining a higher degree of control of these insects. Four field-plot experiments were carried out in 1950 to determine the effectiveness of 9 insecticides when applied to the crop by various procedures.

MATERIALS AND METHODS.[3]—The formulations and concentrations of the insecticides used throughout this investigation in terms of active ingredient per 100 gallons of spray follow: Lindane, 25 per cent wettable powder, 0.25 pound; aldrin, 25 per cent emulsion, 1.0 quart; chlordane, 40 per cent wettable powder, 2 pounds; DDT, 50 per cent wettable powder, 2 pounds; toxaphene, 40 per cent wettable powder, 2 pounds; parathion, 25 per cent wettable powder, 0.25 pound; methoxychlor, 50 per cent wettable powder, 2 pounds; cryolite, 90 per cent wettable powder, 7.2 pounds; and dieldrin, 25 per cent wettable powder, 0.25 pounds. An emulsifier was added to each formulation at the rate of 1–2000.

A weevil-susceptible variety of sweetpotato was used throughout this study.[4]

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 221.

[2] Wallace C. Mitchell and Akira Kubota assisted in carrying out the experiments.

[3] The following manufacturers supplied experimental material: California Spray-Chemical Corp., Richmond, Calif.; Julius Hyman and Co., Denver, Colo.; Niagara Chemical Division, Food Machinery and Chemical Corp., Richmond, Calif.; Nico-Dust Manufacturing Division, Stauffer Chemical Co., San Francisco, Calif.; Pacific Chemical and Fertilizer Co., Honolulu, Hawaii.

[4] This variety, known as HAES 14, was developed by Dr. C. F. Poole, Vegetable Crops Department, College of Agriculture, University of Hawaii, for outstanding baking qualities. The writer is indebted to Dr. Poole for making this investigation possible by his donation of the planting material and the experimental area.

Twelve-inch terminal cuttings of the vines were used as planting material on March 23, 1950.

The following procedures were used in applying the toxicants to the experimental plots:

Experiment 1.—The soil was treated prior to planting and the growing plants were sprayed 5 times during the season.

The soil was irrigated and allowed to soften. A hole 6 inches deep was made and 32 cc. of the insecticidal suspension or emulsion were poured into it by means of a funnel. The planting slip was placed in the hole which was then closed. Each plot was sprayed 5, 10, 14, 16, and 18 weeks after planting. Power equipment was used to apply the insecticide to the foliage and to the soil surrounding the plants. The initial 4 applications were made using a wheelbarrow sprayer at an operating pressure of 100 pounds per square inch and the final spray was applied with a 50-gallon spray rig at 200 pounds pressure. Five materials (lindane, aldrin, chlordane, DDT, and toxaphene) were compared for thier insecticidal effectiveness in this experiment.

Experiment 2.—The terminal cuttings were dipped in an insecticidal suspension before planting, and the plots were sprayed 5 times during the growing season.

The slips were immersed completely and agitated in the insecticidal suspension or emulsion for 30 seconds prior to planting. Thorough wetting of the cuttings was thus assured. The same procedure was used in applying the spray as described for experiment 1. All nine toxicants were used in this experiment.

Experiment 3.—No preplanting treatment was utilized. Five spray applications were made during the growing season. All nine materials were employed in the experiment.

Experiment 4.—The terminal cuttings were subjected to a preplanting dip as described for experiment 2, but no additional protection was given the plants. All nine materials were compared in this experiment.

Within each experiment, the treatments were randomized and replicated 3 times with the exception of those in experiment 4, which were replicated only twice. Each treatment plot consisted of three rows of seven plants.

Twenty weeks after planting (August 7 and 8, 1950) the main stems of the sweetpotato plants of the center row of each plot were harvested. The stems were cut well below the soil surface, and approximately 1-foot lengths were examined for weevil and vine borer damage. The degree of infestation of both weevil and vine borer was rated as follows: 5, uninfested; 4, slight infestation; 3, moderate infestation; 2, heavy infestation; and 1, very heavy infestation. These data are summarized in tables 1 to 4.

The sweetpotatoes were harvested 21 weeks after planting. All potatoes less than 3 inches long were discarded. Each potato was examined for weevil damage. Although both species of weevils were

Table 1.—Comparative effectiveness of insecticides for the control of the West Indian sweetpotato weevil, *Euscepes postfasciatus*, and the sweetpotato vine borer, *Omphisa anastomosalis*, when applied as soil treatments and sprays.

Material	Per Cent Active Ingredients	*Omphisa anastomosalis*		*Euscepes postfasciatus*[2]			
		Per Cent[1] Infested Stems	Infestation Rating[3]	Per Cent[1] Infested Stems	Infestation Rating[3]	Number Roots Examined	Per Cent Infested Roots
Lindane	0.031	5	4.95	5	4.95	236	8.4
Aldrin	0.25	0	5.00	0	5.00	203	0.9
Chlordane	0.25	43	4.38	0	5.00	228	1.0
DDT	0.25	0	5.00	24	4.43	207	0.7
Toxaphene	0.25	5	4.95	0	5.00	246	1.3
Untreated	—	52	3.52	76	2.57	260	15.2
				Least difference for significance:		(19:1)—7.0 (99:1)—9.4	

[1] Twenty-one stems examined in each treatment.
[2] The data include a small amount of damage caused by *Cylas formicarius elegantulus*.
[3] The rating values ranged from "5, no infestation" to "1, very heavy infestation."

Table 2.—Comparative effectiveness of insecticides for the control of the West Indian sweetpotato weevil, *Euscepes postfasciatus*, and the sweetpotato vine borer, *Omphis anastomosalis*, when applied as cutting dips and sprays.

Material	Per Cent Active Ingredients	*Omphisa anastomosalis*		*Euscepes postfasciatus*[2]			
		Per Cent Infested Stems[1]	Infestation Rating[3]	Per Cent Infested Stems[1]	Infestation Rating[3]	Number Roots Examined	Per Cent Infested Roots
Lindane	0.031	5	4.95	5	4.95	197	2.5
Aldrin	0.25	5	4.90	5	4.90	185	0.0
Chlordane	0.25	57	4.29	0	5.00	268	0.3
DDT	0.25	0	5.00	0	5.00	193	0.0
Toxaphene	0.25	14	4.81	0	5.00	210	0.4
Parathion	0.031	5	4.95	10	4.90	223	1.4
Methoxychlor	0.25	57	4.19	52	4.24	246	9.0
Cryolite	0.91	29	4.42	48	3.63	211	6.9
Dieldrin	0.031	48	4.43	0	5.00	271	3.1
Untreated	—	95	1.62	81	2.00	227	31.4
				Least difference for significance:		(19:1)—7.1 (99:1)—9.8	

[1] Twenty-one stems examined in each treatment.
[2] The data include a small amount of damage caused by *Cylas formicarius elegantulus*.
[3] The rating values ranged from "5, no infestation" to "1, very heavy infestation."

present, *Euscepes postfasciatus* was by far the most abundant. The damage was therefore caused primarily by this species. Tables 1 to 4 give the per cent of damage caused by the weevils in sweetpotatoes.

RESULTS.—Table 1 summarizes the results of experiment 1, in which five insecticides were applied as soil treatments and sprays. Lindane, aldrin, DDT, and toxaphene gave excellent protection from the vine borer. Chlordane was ineffective against this insect. All 5 materials adequately controlled the weevil in the stem. Lindane apparently afforded no control of the weevils in the potatoes.

Table 2 summarizes the results of experiment 2, in which the 9 insecticides were applied as cutting dips and sprays. Lindane, aldrin, DDT, toxaphene, and parathion were effective in controlling the vine borer. Cryolite was somewhat less effective, and chlordane, methoxychlor, and dieldrin were ineffective. The cryolite- and methoxychlor-treated plots had high infestations of the weevil in the stem; however, the damage to the potatoes in all the treated plots was significantly less than that of the check plots.

Table 3 summarizes the results of experiment 3, in which the nine insecticides were applied only as sprays. Lindane, DDT, and parathion controlled the vine borer. None of the treatments protected the stems from weevil attack; however, the potatoes in all the treated plots were significantly less damaged by weevil than the potatoes in the check plots.

Table 4 summarizes the results of experiment 4 in which the 9 insecticides were applied only as cutting dips. None of the insecticides was effective in controlling the vine borer or the weevil in the stem. The damage to the potatoes in the plots treated with DDT, dieldrin, and chlordane, although significantly less than in the untreated plots, was too great for these treatments to be considered satisfactory.

OFF-FLAVORS AND RESIDUES.—A taste panel[5] was conducted to determine whether any of the insecticide treatments affected the natural flavor of the sweetpotatoes. After harvesting, the sweetpotatoes were cured by storing them for 2 to 3 weeks on wire racks in a well-aerated farm building. Cured potatoes from the treated plots were boiled and baked, and were compared for flavor with sweetpotatoes from the untreated plots. The results of the panel were subjected to statistical analysis, and no objectionable flavors which could be attributed to any of the insecticidal treatments were discovered.

Benzene extracts of the treated sweetpotatoes from experiment 2 were analyzed

[5] The writer is indebted to Miss Kathryn J. Orr, Nutrition Department, Agricultural Experiment Station, University of Hawaii, for supervising the taste panel.

Table 3.—**Comparative effectiveness of insecticides for the control of the West Indian sweetpotato weevil, *Euscepes postfasciatus*, and the sweetpotato vine borer, *Omphisa anastomosalis*, when applied as 5 sprays during the season.**

Material	Active Ingredients	*Omphisa anastomosalis*		*Euscepes postfasciatus*[2]			
		Per Cent Infested Stems[1]	Infestation Rating[3]	Per Cent Infested Stems[1]	Infestation Rating[3]	Number Roots Examined	Per Cent Infested Roots
Lindane	0.031	5	4.95	38	4.52	242	0.9
Aldrin	0.25	20	4.75	45	4.36	222	0.0
Chlordane	0.25	19	4.48	71	4.09	217	0.0
DDT	0.25	0	5.00	67	4.19	194	0.0
Toxaphene	0.25	33	4.67	76	4.05	265	0.9
Parathion	0.031	0	5.00	86	3.52	234	1.9
Methoxychlor	0.25	24	4.76	100	3.23	230	3.4
Cryolite	0.91	29	4.43	81	3.81	226	0.9
Dieldrin	0.031	38	4.57	81	3.95	273	0.0
Untreated	—	57	4.00	86	2.23	286	20.0
				Least difference for significance:		(19:1)—5.6 (99:1)—7.5	

[1] Twenty-one stems examined in each treatment.
[2] The data include a small amount of damage caused by *Cylas formicarius elegantulus*.
[3] The rating values ranged from "5, no infestation" to "1, very heavy infestation."

for insecticidal residue.[6] DDT, chlordane, and toxaphene resideues were determined by the total organic chloride method (Carter 1949), parathion by the method of Averill & Norris (1948), aldrin by the phenylazide colorimetric method (Danish & Lidov 1950), and dieldrin by infrared spectroscopy. The following results were obtained: DDT, 0.18 ppm.; chlordane, 0.22 ppm.; aldrin, 0.0 ppm.; dieldrin, 0.0 ppm.; toxaphene, 0.38 ppm.; and parathion, 0.02 ppm.

DISCUSSION AND CONCLUSIONS.—This study was conducted in an area which had been continuously planted in sweetpotatoes for varietal tests for several years. No particular attempt had been made to control the sweetpotato insects in this area, and the vine borers and weevils were extremely abundant. A field from which a crop containing a high per-

[6] The writer wishes to express his appreciation to Miss Amy Tanada, chemist, Oriental Fruit Fly Investigations, U.S.D.A., Honolulu, Hawaii, and Dr. A. A. Danish of Julius Hyman & Co., Denver, Colo., for the chemical determinations.

Table 4.—**Comparative effectiveness of insecticides for the control of the West Indian sweetpotato weevil, *Euscepes postfasciatus*, and the sweetpotato vine borer, *Omphisa anastomosalis*, when aprlied as cutting dips.**

Material	Per Cent Active Ingredients	*Omphisa anastomosalis*		*Euscepes postfasciatus*[2]			
		Per Cent Infested Stems[1]	Infestation Rating[3]	Per Cent Infested Stems[1]	Infestation Ratings[3]	Number Roots Examined	Per Cent Infested Roots
Lindane	0.031	57	3.57	93	1.92	148	42.4
Aldrin	0.25	43	3.71	100	1.57	209	30.8
Chlordane	0.25	50	3.86	64	4.00	216	19.3
DDT	0.25	71	3.36	64	3.50	211	11.8
Toxaphene	0.25	93	1.93	100	1.65	174	35.0
Parathion	0.031	100	2.00	100	2.00	137	41.6
Methoxychlor	0.25	36	3.93	93	2.50	191	29.4
Cryolite	0.91	100	1.64	100	1.63	265	35.5
Dieldrin	0.031	57	4.14	21	4.71	184	15.2
Untreated		100	1.50	100	1.50	165	45.5
				Least difference for significance:		(19:1)—16.8 (99:1)—22.5	

[1] Fourteen stems examined in each treatment.
[2] The data include a small amount of damage caused by *Cylas formicarius elegantulus*.
[3] The rating values ranged from "5, no infestation" to "1, very heavy infestation."

centage of weevil-infested potatoes had recently been harvested was chosen for the location of the experimental plots. There was a heavily infested planting of sweetpotatoes in the adjacent field throughout the investigation. This area was selected to test the effectiveness of the organic insecticides and the various methods of their application under extremely unfavorable conditions.

None of the insecticides, when applied only as cutting dips was effective in controlling the vine borer. In those experiments which included a spray program, the use of DDT, parathion, and lindane resulted in excellent control of this species while the use of aldrin seemed promising.

The adults and larvae of the weevil attack both the stems and roots of the sweetpotato plant. Although the damage to the roots is of more direct practical importance, the stem infestation may serve as a source for the build-up of the weevil population within a particular field and thus increase the subsequent damage to the potatoes. The stems may also serve as a means of infesting a new area by the transport of the weevil in terminal cuttings.

Preplanting treatment, followed by a spray schedule, seemed essential in preventing a build-up of weevils in the stems. When this procedure was followed, all the toxicants except methoxychlor and cryolite gave adequate protection. However, when the preplanting treatment was not followed by spraying, or when no preplanting treatment was used, none of the toxicants controlled the weevils. The potatoes, however, were adequately protected by all of the materials applied as sprays, regardless of whether a preplanting treatment was used.

Where both the vine borer and the weevil are apt to become damaging, a single material which controls both species is preferred. Of the materials tested, DDT, aldrin, lindane, and parathion gave the best protection from these insects. The use of DDT, however, may require the addition of an acaracide. A severe infestation of the two-spotted mite, *Tetranychus bimaculatus* (Harvey), occurred during the latter part of the study in the DDT- and methoxychlor-treated plots. The addition of wettable sulfur at the rate of 5 pounds per 100 gallons to these materials during the final application appreciably reduced the mite damage.

Further work with the more effective insecticides is planned in order to determine the most practical methods of application for the control of these insects.

SUMMARY.—Four experiments were conducted in 1950 to determine the effectiveness of lindane, aldrin, chlordane, toxaphene, DDT, parathion, methoxychlor, cryolite, and dieldrin in controlling two species of sweetpotato weevils, *Euscepes postfasciatus* (Fairm.) and *Cylas formicarius elegantulus* (Summers), and the sweetpotato vine borer, *Omphisa anastomosalis* (Guen). The materials were used as soil treatments, preplanting cutting dips, sprays, or combinations of these methods of application.

DDT at 2.0 pounds of active ingredients per 100 gallons, lindane and parathion at 0.25 pound of active ingredients per 100 gallons, and aldrin as an emulsion at 0.25 per cent active ingredients gave excellent protection from the weevils and vine borer when applied as cutting dips in combination with 5 sprays during the season despite the poor sanitary conditions in the field.

None of the treatments resulted in the potatoes having appreciable residues or off-flavors.

LITERATURE CITED

Averill, P. R., and M. V. Norris. 1948. Estimation of small amounts of 0,0-diethyl 0-p-nitrophenyl thiophosphate. Anal. Chem. **20:** 753–6.

Carter, Roscoe H. 1949. Report on DDT as spray residue on foods. Jour. Assoc. Off. Agr. Chem. **32**(2): 353–9.

Danish, A. A., and R. E. Lidov. 1950. Colorimetric method for estimating small amounts of aldrin (compound 118). Anal. Chem. **22**(5): 702–6.

Holdaway, F. G. 1941. Insects of sweetpotato and their control. Hawaii Agr. Expt. Sta. Progress Note **26:** 1–7.

Tucker, R. W. E. 1937. The control of Scarabee (*Euscepes batatae* Waterh.) in Barbados. Agr. Jour. (Barbados). **6**(4): 133–54.

Toxicity of Various Compounds as Fumigants to Eggs and Larvae of the Oriental Fruit Fly[1]

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The fumigant most widely used for the treatment of fresh commodities to destroy insect infestations is methyl bromide. This material, although toxic to fruit flies, must be used in concentrations that cause injury to some products. In a search for suitable fumigants with less injurious effects, a number of compounds were tested in Hawaii to determine their toxicity to the immature stages of the oriental fruit fly, *Dacus dorsalis* Hendel. The results with 53 compounds and mixtures against eggs and third-instar larvae are presented to illustrate the relative toxicities of these materials when used under similar conditions.

The naked egg and larval stages were selected for these studies because they could be tested at any desired age, they were easy to handle in this form, and it was considered that the materials effective against these forms could be tested later on infested fruits and vegetables.

The eggs were obtained by exposing caged flies to orange-rind sections paraffined to glass plates. The larvae were reared on mascerated carrot or papaya medium. These larvae were in the third instar approximately 8 to 10 days from the time of hatch.

All the materials were first tested against eggs 24 to 26 hours old, when larval development within the eggs was practically complete. Ten of the materials were selected for comparative testing of eggs 30 minutes to 2 hours old with eggs 23 to 26 hours old fumigated simultaneously. A total of 42,300 eggs and 16,475 larvae was used in these studies.

Method of Testing.—Ten 5-gallon friction-top tins were adapted for fumigating in the following manner: They were first made gas-tight by grinding the edges of the cover and the groove so as to make a tight seal. A hole to fit a No. 6 rubber stopper was punched in the center of the cover. A piece of hardware cloth approximately 4 inches square was suspended 2 inches below the opening to support a sheet of No. 2 filter paper, on which the test materials were applied from a microburette inserted through the opening in the lid. For each test 50 eggs were placed in groups of 5 in petri dishes on moistened black-dyed filter paper for ease in counting and observing hatch. The petri dishes were placed in the fumigating tins on a low platform to elevate them a few inches from the bottom. The larvae were placed in groups of 25 in 50-milliliter beakers covered with fine muslin and fastened with rubber bands to prevent larvae from escaping.

The exposure period was 2 hours. No attempt was made to control temperatures which ranged from 71° to 80° F. After fumigation the petri dishes and beakers were removed from the fumigating tins and allowed to air for 1 hour to eliminate absorbed gas, and then the petri dishes were covered and the eggs and larvae were maintained at a constant temperature of 80° F. Readings were made 24 hours after fumigation to determine egg hatch and larval mortality, and from these data mortalities were calculated by the use of Abbott's formula. Natural mortality was estimated from similar lots of non-fumigated eggs and larvae.

Mortality curves were established for each material, and these curves were used to fix dosage levels required for LD-50 and LD-95. Some of the compounds, such as chloroacetonitrile, acrylonitrile, 1-bromo-2-chloroethane, ethylene dibromide, and methyl iodide, were so toxic that it was impossible to measure the undiluted material in dosages less than those required for 100 per cent mortality. These compounds were diluted with carbon tetrachloride, which was relatively ineffective as a fumigant.

Results:—Mortality curves for three of the compounds tested are shown in figure 1, and the LD-50 and LD-95 for all the compounds tested, in table 1.

The following materials were more toxic to larvae than to eggs: Ethyl thiocyanate, methyl thiocyanate, propylene oxide, 3-chloro-2-methylpropene, 1,1-dichloro-1-nitroethane, chlorobromopropene, allyl

[1] The authors greatly appreciate the assistance of Glenn Finney, of the University of California, Division of Biological Control, in furnishing fruit fly eggs and larvae for these studies.

Table 1.—Effectiveness of various compounds and mixtures used as fumigants against naked eggs (23 to 26 hours old) and naked third-instar larvae of the oriental fruit fly. Dosages in milligrams per liter.

Compound of Mixture	Eggs		Larvae	
	LD-50	LD-95	LD-50	LD-95
Acetic acid, chloro-, ethyl ester	6.2	13.5	1.4	3.6
Acetonitrile	44	75	>82.4	
Acetonitrile, chloro-	1.2	1.5	<1.3	<1.3
Acetonitrile, chloro-, 25% and carbon tetrachloride 75%	8.2	15.5	<1.9	1.9
Acrylonitrile	1.2	1.6	<1.2	1.6
Acrylonitrile 50% and carbon textrachloride 50%	3.7	11	1.7	4.9
Allyl alcohol	5.8	13.2	<1.1	1.5
Allyl bromide	15	24	1.8	7.5
Allyl chloride	71	105	70	>98.6
Benzene, chloroethyldichloro-[1]	>140*		>140*	
Butenes, dichloro[2]	2.3	5.3	1.4	2.5
1,3-Butadiene, hexachloro-	>174.6*		>174.6*	
tert-Butyl alcohol	>83		>83	
Butyl bromide	83	195	47	90
Carbon disulfide	53	92	56	89
Carbon tetrachloride	>167.8		>167.8	
1,4-Dioxane	115	210	>109	
Methylbromide-ethylenedichloride-carbontetrachloride mixture[3]	5.4	11	61	125
Ethane, 1-bromo-2-chloro-[4]	<2.2	<2.2	<2.2	2.3
Ethane, 1-bromo-2-chloro-, 10% and carbon tetrachloride 90%	10	16.5	15	44
Ethane, 1-bromo-2-chloro-, 5% and carbon tetrachloride 95%	22.5	34	21	52
Ethane, 1,1-dichloro-	>123.6		>123.6	
Ethane, 1,1-dichloro-1-nitro-	24	60	<1.9	<1.9
Ethane, *sym*-tetrachloro-	25	68	20	43
Ethane, 1,1,1-trichloro-	28	69	<139	
Ether, bis(chloroisopropyl)[5]	>116.8*		<116.8*	
Ethyl formate	>104			
Ethyl thiocyanate	11	38	3.1	7.3
Ethylene dibromide	<2.9	<2.9	<2.9	<2.9
Ethylene dibromide 5% and carbon tetrachloride 95%	2.8	8.6	7.8	19
Ethylene dichloride	2.3	5.9	38	120
Ethyelene dichloride 75% and carbon tetrachloride 25%	3.2	7.3	60	140
Ethylene oxide	6.2	12.0	8.7	17.0
Ethylene, 1, 1,2-trichloro-	>153.2	—	>153.2	—
Hydrocyanic acid	10	26	1.3	2.8
Methyl bromide	15	24.5	9.2	18.5
Methyl formate	65	110		
Methl iodide	<2.9	<2.9	<2.9	4.2
Methyl iodide 5% and carbon tetrachloride 95%	25	48	—	—
Methyl iodide 10% and carbon tetrachloride 90%	—	—	36	82
Methyl thiocyanate	2.7	8.5	<1.4	<1.4
Pentanes, dichloro-[1]	>112.2*	—	>112.2*	—
Pentane, 2,2,4-trimethyl-	>72.8	—	>72.8	—
Propane, 1,2-dichloro-	70	180	>122	—
Propane, 1-bromo-2-chloro[6]	12	26	120	195
Propane, 1,2,3-trichloro-	15.5	130*	31	59.7*
Propene, 3-chloro-2-methyl-	>97.4		29	47
Propene, 1,3-dichloro-	3.9	8.7	6.0	13.5
Propene, 2,3-dichloro-	16.5	27.5	11.5	27.0
Propene, 1,2,3-trichloro-	23	58	45	>148
Propionic acid, methyl ester	>96.6	—	>96.6	—
Propylene oxide	>87.4	—	18.5	28.0
Chlorobromopropene, Tech.[7]	5.9	8.7	2.0	3.1

* Volatilization incomplete.
[1] Mixture, exact structure unknown.
[2] Technical grade, mixed isomers.
[3] Methyl bromide—12.6%, Ethylene dichloride—61.4%, Carbon tetrachloride—26.0%. (*Dow-Fume G*)
[4] Ethylene chlorobromide.
[5] Technical grade, exact structure unknown.
[6] Propylene chlorobromide.
[7] Technical chlorobromopropene, mostly 1-chloro-3-bromopropene. (Shell D.S. 840).

Table 2.—Comparative toxicity of various fumigants to young and old eggs of the oriental fruit fly. Dosages in milligrams per liter.

FUMIGANT	EGGS 0.5 TO 2 HOURS OLD		EGGS 23 TO 26 HOURS OLD	
	LD-50	LD-95	LD-50	LD-95
Acetonitrile, chloro-, 25% and carbon tetrachloride 75%	5.7	15.0	5.7	15.0
Acrylonitrile 50% and carbon tetrachloride 50%	1.7	3.2	3.9	8.0
Carbon disulfide	25	40	46	92
Methylbromide-ethylene dichloride-carbon tetrachloride mixture	5.6	10.5	5.2	8.6
Ethane, 1-bromo-2-chloro-, 10% and carbon tetrachloride 90%	10	16	10	16
Ethylene dibromide 5% and carbon tetrachloride 95%	2.8	7.3	2.8	7.3
Ethylene dichloride 75% and carbon tetrachloride 25%	3.9	11	2.9	6.1
Hydrocyanic acid	3.5	12	10	25
Methyl bromide	5.7	10.5	15	24.5
Propene, 2,3-dichloro-	6	13.5	15	25

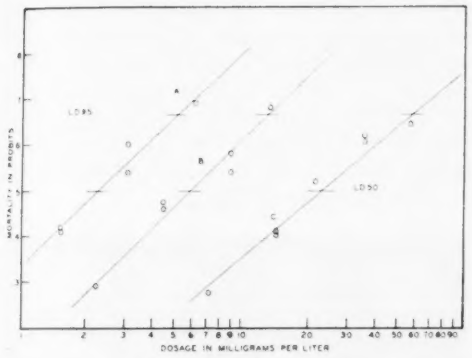

FIG. 1.—Dosage-mortality curves for eggs of *Dacus dorsalis* exposed to (A) dichlorobutenes, (B) allyl alcohol, and (C) 1,2,3-trichloropropene. From similar curves for all the compounds tested the LD-50 and LD-95 values presented in table 1 were obtained.

bromide, allyl alcohol, the ethyl ester of chloroacetic acid, methyl bromide, and hydrocyanic acid.

The compounds more toxic to eggs than larvae were the methyl bromide-ethylene dichloride-carbon tetrachloride mixture, ethylene dichloride, and 1-bromo-2-chloropropane.

The following materials were extremely toxic to both stages: Chloroacetonitrile, methyl iodide, methyl thiocyanate, 1-bromo-2-chloroethane, ethylene dibromide, acrylonitrile, chlorobromopropene, 1,3-dichloropropene, and the ethyl ester of chloroacetic acid.

The results of the tests to determine the effect of age of eggs on the toxicity are presented in table 2. With several of the compounds and mixtures no difference was apparent, but with most of the others the older eggs were very much more resistant. A reverse effect was indicated for the mixture ethylene dichloride, and carbon tetrachloride.

SUMMARY.—Fifty-three compounds and mixtures were tested to determine their value as fumigants against the oriental fruit fly, *Dacus dorsalis* Hendel. The tests were conducted in 5-gallon friction-top tins using naked eggs and third-instar larvae. LD-50 and LD-95 values were determined. A differential effect between eggs and larvae was apparent with several compounds. Materials extremely toxic to both stages were chloroacetonitrile, methyl iodide, methyl thiocyanate, 1-bromo-2-chloroethane, ethylene dibromide, acrylonitrile, chlorobromopropene, 1,3-dichloropropene, and the ethyl ester of chloroacetic acid. As a rule older eggs were more resistant to fumigation than younger eggs.

Dips for the Citrus Blackfly as a Possible Treatment for Mexican Limes Boxed for Export[1]

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Living immature forms of the citrus blackfly, *Aleurocanthus woglumi* Ashby, on foliage included with Mexican sour limes have been intercepted by Federal quarantine inspectors on the Mexican-American border on numerous occasions during the last several years. Most of these interceptions have been made from the 100,000 or more boxes of Mexican limes imported each year by various American fruit companies, which usually grade and repack the fruit at point of entry before it is distributed in the United States. With the citrus blackfly spreading in Mexcio, and as long as the present methods of packing limes for export prevail, there is ever the danger that this insect will become established on the border at some point such as Laredo, Texas, where approximately 90 per cent of the fruit is imported and where citrus is grown. To obtain some idea of the hazard, an experiment was made to determine the emergence of the citrus blackfly from infested lime foliage in boxes of limes packed for export. Of the total adult blackflies recorded, 11 per cent emerged after 12 days of storage at room temperature (approx. 60°–70° F.). With limes only 3 to 7 days in transit from grower to the border, the threat is obvious. The treatment of boxed limes was studied for possible recommendation as a measure to supplement inspection to prevent extablishment of the citrus blackfly in the United States. Studies to develop a fumigant or a tank dip were made, but only the work with dips is reported.

Procedure.—Materials showing promise were tested extensively (1) to obtain mortality data on large numbers of the citrus blackfly, and (2) to observe how the fruit withstood the treatment. Populations of the blackfly were made up of pupae, with adults beginning to emerge, on foliage. This foliage, from the State of Morelos, was always treated within 48 hours after it was picked. After treatment the fruit and foliage were removed from the boxes and dried. The fruit, a box at a time, was spread on top of a table and dried by a 16-inch electric fan. Then it was equally divided in four slatted trays placed in special holding boxes which provided ventilation but did not allow the fruit to desiccate. Storage was at room temperature for 40 days, and the fruit was examined for rot and markings due to treatment (Fig. 1) at 10-day intervals. After the foliage had been dried at room temperature over 0.5 inch-mesh hardware wire cloth, 40 leaves per replicate (4 to 6 replicates per test) were held on blotting paper in 1-quart square mason jars. The jar was ventilated by a 0.3 inch aperture in the lid sealed with medium-weight muslin. All jars were held horizontally in a Carrier cabinet kept at 77° F. (±1°) and at approximately 60 to 75 per cent relative humidity. The jars were examined after 11 or 12 days, when flies on leaves stored under these conditions cease to emerge.

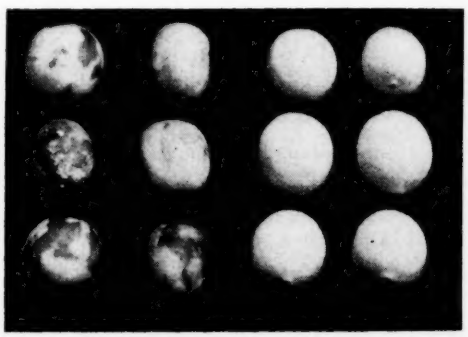

Fig. 1.—Limes damaged as a result of treatment with 3 per cent oil emulsion on the left, and unmarked control fruit on the right.

Usually fruit from the State of Michoacan, which is of the highest quality and stores well, was used for treatment. Two boxes, as packed for export—700 to 800 limes each, weighing 60 pounds net and including 160 to 240 leaves interspersed—usually made up a test. Each box was submersed for 5 minutes in 140-liters (37 gallons) of mix prepared in a 55-gallon drum. The drum, mounted horizontally, had an opening on the upper side large

[1] Paper presented at meeting of the American Association of Economic Entomologists held at Denver, Colo., Dec. 18–21, 1950.

[2] Other co-authors of this paper are R. Doelker and R. Villase or but do not appear as such as they are not members of the American Association of Economic Entomologists. Acknowledgments are due Paulino Rojas and Francisco Guiza for their assistance in these studies.

enough for the insertion of single boxes of fruit. Highly stable emulsions were agitated by taking the mixture from the bottom of the drum by means of a half-inch electrically driven pump and releasing it from above. Usually a hose was placed on the outlet pipe and the mixture released below the surface to minimize the formation of foam. It is believed that the movement of the boxes of limes in submersion is sufficient agitation for stable emulsions. For commercially prepared spray oil emulsions and emulsive oils which break readily, the hose was raised above the surface to obtain better agitation; agitation was supplemented by continuous use of a paddle during the time of submersion.

SPRAY OIL EMULSIONS.—Treatment of Mexican limes has been required by the California Department of Agriculture for several years to prevent possible introduction of several surface insects, principally scales. Armitage & Steinweden (1946) found that submergence of limes for 3 minutes in 3 per cent oil emulsion of 70 seconds Saybolt viscosity at 100° F. and 90 per cent unsulfonated residue gave satisfactory control with minimum injury to fruit that was properly dried, whereas fruit moving to the retailer without being dried often arrived in an unsatisfactory condition.

Studies made by the authors in Mexico showed that oil emulsion was harmful to Mexican limes, but that boxed limes left unopened several days after submergence held up better than fruit that was removed immediately and dried before being place in storage at 60° to 70° F. However, for convenience, the treated fruit was dried with an electric fan even though it is conceded that handling the wet fruit to dry it may cause some damage. Both the light-medium emulsion and the light-medium soluble or emulsive oil were prepared with water only. Loss of fruit (Table 1) treated in 3 per cent light-medium emulsion was significantly different at the 1 per cent level from the loss of fruit from natural causes in the controls. The effect of these treatments on the flavor of fruit sampled after 16 to 32 days' storage was found in 2 of 5 experiments to be significantly deleterious as appraised by panels of 14 to 16 persons. A significant differential in fruit loss was also recorded with oil emulsion at 1.5 and 2 per cent, emulsive oil at 1.67 per cent with cube added, and 3 per cent kerosene emulsion. The emulsive oil also significantly affected the flavor of the fruit juice.

Table 1.—Accumulative percentage loss after 40 days' storage of limes treated with 3 per cent light-medium oil emulsion. (Analysis of variance made on basis percentage lost in each replicate at each of the 4 examinations made at 10, 20, 30, and 40 days.)

SOURCE OF FRUIT	CONDITION OF FRUIT WHEN TREATED	PER CENT LOSS OF FRUIT	
		Treated	Control
Apatzingan, Michoacan	Ripening (?)	55.7 53.5[1]	28.8
Nueva Italia, Michoacan	Ripening	33.2 57.0[2]	20.0
Tomellin, Oaxaca	Mature-green	17.2	9.0
Apatzingan, Michoacan	Ripe	46.7	26.5
Llera, Tamaulipas	Green and immature	83.4	49.2
Sayula, Veracruz	Mature-green and ripe	74.9	37.6

[1] Duplicate box held without drying and opened after 10 days.
[2] Including 3.9 oz. cube (4.2% rotenone content) per gallon of oil.

Satisfactory control of the citrus blackfly after submersion for 5 minutes in 3 per cent oil emulsion was not always obtained. In one instance 36 of the 240 leaves included in a box of limes had some pupae untouched by the emulsion. Six blackflies of an estimated population of 5253 subsequently emerged from these pupae. Later it was observed that if cube was included in the emulsion better coverage was provided and no flies emerged. The quick breaking characteristic of oil emulsions is a distinct disadvantage when they are used for dipping, because of the objectionable oil deposit on fruit and the supposedly rapid depletion of the oil content of the emulsion.

PROCESS OIL EMULSIONS.—The Prorex oils of Socony-Vacuum,[3] of high paraffinicity and approximately 88 to 93 per cent unsulfonated residue, known as process oils, were suggested for trial. Pearce

[3] Preliminary results with these oils, at the time available to us, were so promising that experiments were continued with them. Experiments with similar oils of other companies, now on hand, may prove them to be equally effective.

et al. (1942) found that similar oil of high paraffinicity of dormant type was of high ovicidal efficiency as a spray for the fruit tree leaf roller, *Archips argyrospila* (Wlkr.). Later Chapman *et al.* (1943) found the same type summer-spray oil effective for killing eggs of the oriental fruit moth, *Grapholitha molesta* (Busck), the codling moth, *Carpocapsa pomonella* (L.), and the eye-spotted bud moth, *Spilonota ocellana* (D. & S.). These oils[1] are odorless and tasteless when used as impregnants, are stable toward oxidation, and are recommended by the manufacturers for the treatment of many organic and industrial products. With such characteristics it was reasoned that they should cause minimum harm to citrus fruit and effect control of the blackfly included with boxed fruit. Oil C[1] (viscosity 58–60 sec.) and Oil P[1] (viscosity 100–105 sec.) at 2 per cent dilution were emulsified with 0.2 per cent of sorbitan monooleate polyoxyalkylene derivative and 0.2 per cent of sorbitan monolaurate[2] and the 1.5 per cent dilution with 0.15 per cent of each of these emulsifiers. Dodecyl toluene sulfonate[4] was added to Mexico City tap water at the rate of 1.6 per cent of the final mix before the oil containing the emulsifiers was added. Based on commercial quantities, the cost of materials required for a 1.5 per cent emulsion for 100 gallons of mix totals $4.10, making the cost of each box treated only a few cents. When cube was included in these oil treatments, it was added at the rate of 4.14 ounces (4.2 per cent rotenone content) per gallon of oil.

A highly stable emulsion of Oil P[1] provides a dip of uniform concentration until all of it is used. Biological tests and physical observations were made in an attempt to determine the stability of the emulsion; no chemical tests were made. Two experiments were run for a biological measure in which the emulsions were diluted sufficiently to allow some adult blackfly emergence. A 0.375 per cent Oil P emulsion was used in one experiment and a 0.5 per cent emulsion in the other. Series of 100 crates built on the scale of the export crates, but of only about 3.33 per cent the capacity and with infested foliage interspersed. were used for dipping in 4 gallons of mix. In neither experiment did the mortality decrease as the last of the series was submersed, though 50 per cent of the mix was absorbed by fruit, paper and crate, or some slight spillage. Samples of both the emulsions taken before and after treatment of the series were stored 4 months with no stratification or any layer forming on the surface. These mixes had the appearance of colloidal emulsions and they seemed to remain uniform and stable. Emulsions of 1.5 and 2 per cent concentration remained stable in 37-gallon lots when held for several weeks.

An emulsion prepared with 3 per cent of Oil P was not found injurious to limes (Table 2) and was subsequently tested at dilutions of 1 and 2 per cent with similar results (Table 2). In table 3 Oil P of high viscosity and Oil C of medium viscosity were compared in two experiments at 1.5 and 2 per cent dilutions with no apparent harm to the fruit.

Because control of surface insects such as scales might need to be considered as well as the citrus blackfly, Oil P emulsion at 1.5 and 2 per cent, with and without

Table 2.—Accumulative percentage loss of limes treated with "Oil P"[1] emulsions.

Days in Storage	Loss of Limes			
	3%	2%	1%	Control
Experiment 1 (1535 fruits treated)				
10	2.2	—	—	1.2
20	3.2	—	—	2.3
30	9.0	—	—	7.1
40	19.3	—	—	20.0
Experiment 2 (8655 fruits treated)				
10	4.3	4.6	4.1	4.4
20	10.4	10.1	8.3	9.3
30	21.6	21.7	20.0	22.0
40	45.0	46.5	42.9	43.8

Table 3.—Accumulative percentage loss of limes treated with different process-oil emulsions.

Days in Storage	Loss of Limes				
	Oil P		Oil C		Control
	2%	1.5%	2%	1.5%	
Experiment 1 (7864 fruits treated)					
20	2.0	2.2	3.1	2.6	1.6
40	6.0	7.2	9.1	7.7	6.8
Experiment 2 (7198 fruits treated)					
20	0.6	0.6	1.0	1.1	0.6
40	22.0	25.6	23.3	26.1	23.8

[1] (*Prorex*).
[2] *Tween 81.*
[3] *Spanzo.*
[4] Wetting agent 1959.

Table 4.—**Accumulative percentage loss of limes of different stages of maturity from different areas of Mexico treated with 0.1 P emulsions.**

Condition of Fruit When Treated	Days in Storage	Number of Fruits Treated	Loss of Limes				
			2% Oil P		1.5% Oil P		
			Without Cube	With 8.28 oz. of Cube	Without Cube	With 6.21 oz. of Cube	Control
		Fruit from Tecoman, Colima					
Mature-green	20	7,424	2.5	2.6	1.5	1.5	1.8
	40		48.3	45.2	54.2	45.5	43.0
Ripening	20	5,654	3.6	4.0	1.6	2.6	2.5
	40		53.2	56.1	52.4	50.3	47.2
		Fruit from Apatzingan, Michoacan					
Mature-green	20	7,239	0.8	0.4	0.8	0.7	0.6
	40		11.9	13.6	11.0	9.0	10.0
Ripening	20	6,868	1.0	1.5	2.5	1.6	2.1
	40		19.4	22.0	16.9	15.9	21.0

cube, was tested in two experiments comparing keeping qualities of treated fruit. Limes from two areas of Mexico, and of two stages of maturity were treated. In most of the tests (Table 4) the addition of cube caused no deleterious effect on the fruit and mature-green fruit held up better in storage than did ripening fruit. Source of fruit and the lapse in time from picking to treatment are also believed to cause variance in results. At the time of treatment the fruit from Colima was not of the same high quality as that from Michoacan, which is usually of standard quality and is apparently quite resistant to damage by the oil treatment (Table 4).

In the foregoing experiments with oils (Tables 2, 3, and 4), a total population of 126,000 mature pupae on lime foliage interspersed with fruit was submersed for 5 minutes in process oil emulsions at the following concentrations:

Oil P:		1%	18,540
3%	15,124	1% plus cube	966
2%	24,293	Oil C:	
2% plus cube	3,344	2%	12,162
1.5%	27,518	1.5%	14,689
1.5% plus cube	6,837	1.5% plus cube	2,527

Although complete kill was recorded except in the case of 1 per cent oil (99.97 per cent), some of these populations are not considered entirely adequate. However, when it is taken into consideration the very low populations which should by chance be included with fruit arriving at the border, these treatments can in all probability be considered adequate to afford security. Interceptions made of living immature forms at the border have averaged about 1 per month during the last 5 years. Usually the infestations involve few leaves and a low population.

Emulsions of Oil P at 1, 1.5, 2, and 3 per cent do not harm the flavor of limeade made up as follows: Lime juice 80 ml. (from 16 fruits of a test), water 720 ml., and sugar 50 grams. The ratings given in table 5 demonstrate that in three experiments panels of 14 to 16 persons found it impossible to detect a difference between limeade made of treated fruit and that from the controls. As is to be expected with a variability in individual fruits and personal dislike for undiluted lime juice, there were more of the fair and poor ratings for fruit sections sampled than there were for the limeade. In no case was significant difference found between samples of limeade or fruit sections of treated and untreated fruit.

OTHER PREPARATIONS.—Materials for dips other than oils which leave no poisonous residue have recently been considered (Table 6). They are emulsions of 0.05 and 0.075 per cent allethrin (75 per cent pure) and 0.02 per cent pyrethrins which each effected 100 per cent kill of an estimated population of 8,519 blackfly pupae. Allethrin is not harmful to the fruit and does not affect flavor, but its status is questionable because of its present high cost. Pyrethrum extract, like the allethrin, emulsified with 0.05 per cent each of the commercial emulsifiers 0.5 per cent of dodecyl toluene sulfonate, is not harmful to fruit or to its flavor (appraisals were

Table 5.—Flavor appraisals of limes treated with 0.1 P emulsions.

Per Cent of Oil Emulsion	Days Limes Were in Storage	Ratio of "Very Good" and "Good" Ratings to "Fair" and "Poor" Ratings			
		Limeade		Cut-fruit Sections	
		Treated	Control	Treated	Control
		Experiment 1			
3	16	11:3	8:6	11:3	8:6
		Experiment 2			
	22	14:1	14:1	12:3	13:2
	29	13:2	13:2	9:6	11:4
2	22	12:3	14:1	11:4	13:2
	29	12:3	13:2	11:4	11:4
1	22	14:1	14:1	13:2	13:2
	29	12:3	13:2	12:3	11:4
		Experiment 3			
2	22–23	16:0	15:1	13:3	10:6
2[1]	22–23	15:1	15:1	10:6	10:6
	21–22	14:1	12:3	10:5	11:4
2	21–22	12:3	12:3	8:7	11:4
1.5	22–23	16:0	15:1	12:4	10:6
1.5[1]	22–23	15:1	15:1	10:6	10:6
	21–22	13:2	12:3	10:5	11:4
1.5	21–22	15:0	12:3	12:3	11:4

[1] Prepared with cube.

made by 15 persons 18 days after treatment). It also leaves the fruit in better keeping condition than even the control, an indication of possible prophylactic effects. Cost of this emulsion is approximately 6 dollars for 100 gallons, or only 50 per cent more than the Oil P emulsion. Further study of these two compounds on limes of variable qualities and from different sources in Mexico is needed.

SUMMARY.—During the last several years living immature forms of the citrus blackfly, *Aleurocanthus woglumi* Ashby, have been intercepted on the Mexican-American border on foliage included with sour limes from Mexico. As a preventive for establishment of the blackfly at the border, development of tank dips has been studied for possible recommendation for treatment of boxed limes.

Tank dips were prepared in the laboratory in a 55-gallon drum, and whole boxes of limes were submersed for a test. Infested foliage was interspersed with the fruit to obtain mortality data. Fruit was stored for 40 days at room temperature with examinations at 10-day intervals.

Commercially prepared spray oil emulsions and emulsive oils caused significant fruit loss and affected its flavor.

From 126,000 citrus blackfly pupae treated with process oil emulsions made of Oils P and C only a few survivors were recorded at the 1 per cent dilution, which contained no cube.

Socony-Vacuum process oils known as *Prorex P* and *Prorex C*, emulsified with sorbitan monooleate polyoxyalkylene derivative and sorbitan monolaurate and a wetting agent known as dodecyl toluene sulfonate, were tested extensively at 1 to 3 per cent dilutions. In experiments with these emulsions almost 100 60-pound boxes of limes were used without injury to the fruit, provided it was in good condition at time of treatment.

None of the panels of 14 to 16 tasters detected any deleterious effect on flavor of limes treated by the process oil emulsions.

Allethrin and 20 per cent pyrethrum extract, both emulsified as in the process oil emulsions but with much less of the emulsifiers and wetting agent, showed promise as dips but require further study. No effect on flavor was detected and all the blackfly pupae treated were killed.

Table 6.—Accumulative percentage loss of limes treated with different emulsions.

Days in Storage	Loss of Limes				
	Oil P	Allethrin		Pyrethrins	
	1.5%	0.05%	0.075%	0.02%	Control
	Experiment 1 (7,248 fruits treated)				
20	1.0	1.2	0.7	0.8	1.0
40	7.1	5.2	6.3	4.7	6.9
	Experiment 2 (7,110 fruits treated)				
20	1.6	1.1	2.1	1.0	1.5
40	16.2	18.3	19.8	17.2	19.0

LITERATURE CITED

Armitage, H. M., and John B. Steinweden. 1946. Tolerance of citrus fruits to methyl bromide as a fumigant. Calif. Citrograph 35: 21–9.

Chapman, P. J., G. W. Pearce, and A. W. Avens. 1943. Relation of composition to the efficiency of foliage or summer type petroleum fractions. JOUR. ECON. ENT. 36(2): 241–7.

Pearce, G. W., P. J. Chapman, and A. W. Avens. 1942. The efficiency of dormant type oils in relation to their composition. JOUR. ECON. ENT. 35(2): 211–20.

Insecticide Tests Against Plum Curculio[1]

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The cage tests reported herein were made to evaluate insecticides against plum curculio adults. This insect is a major pest of peaches in Arkansas. Formerly lead arsenate sprays have been relied on for control. Many growers have obtained satisfactory control for many years with this material. The number of applications of lead arsenate that may safely be made is limited since it is injurious to the trees under certain conditions. Also it is slow to kill curculios.

The purpose of the tests conducted during 1949 and 1950 was to determine if a more satisfactory insecticide for curculio control could be found. A material more quickly toxic to plum curculio and less injurious to peach trees than lead arsenate would be desirable. Any insecticide used in Arkansas for curculio control should be compatible with zinc sulfate-lime, a fungicide used in a number of applications for control of bacterial spot. While data from cage tests should be useful in indicating toxicity of insecticides to plum curculio, final conclusions must be based on field tests.

PROCEDURE.—All the sprays for cage tests were applied with a small power sprayer. A short rod with two nozzles was used. Pressure was maintained at 200 pounds to a square inch. The trees were of the Elberta variety in their third growing season.

Cages were placed on the trees shortly after the spray had dried. These cages were made of 16 mesh screen wire and were fitted with a cloth sleeve at one end. They were approximately 6 inches in diameter and 15 inches long.

Ten curculio adults were placed in each cage. During hot weather the beetles were refrigerated before caging to facilitate counting and handling. All these beetles were collected by jarring unsprayed trees not more than one day before they were caged.

The number of beetles dead when counts were made was usually determined without removing the cage, unless the test was being terminated. Jarring the caged limb usually caused all live beetles to drop to the bottom of the cage. Dead beetles could normally be determined by the position of the legs. Beetles having the legs stretched out and not feigning death or moving the legs when the abdomen was pressed were considered dead.

In addition to the insecticide under test, all sprays contained 6 pounds of zinc sulfate (36 per cent zinc) and 8 pounds of hydrated lime to 100 gallons unless it is indicated otherwise.

RESULTS 1949.—Sprays were applied at Clarksville on April 1, April 21, and May 12. In addition to the insecticide and zinc sulfate-lime mixture 5 pounds of wettable sulphur to 100 gallons was used in all except one of the sprays on May 12. A single tree was sprayed on each date and two cages were placed on each tree making a total of six cages or 60 beetles for each treatment. The counts made at the end of 12 days after the beetles were caged were used to determine effectiveness of the various materials. The different dates of applications were used as replicates in the analysis of variance. These data are shown in table 1. Parathion and chlordane appeared to be the most effective materials tested although they were not significantly better than benzene hexachloride (5 lbs. of 6 per cent gamma isomer to 100 gal.) toxaphene, or the high dosage of lead arsenate (6 lbs.). Lead arsenate plus DDT was significantly better than lead arsenate alone. All treatments except

[1] Research paper No. 1022, Journal Series, University of Arkansas. Published with the permission of the director of the Arkansas Agricultural Experiment Station.

Table 1.—Effectiveness of various insecticides in killing adult curculios after 12 days in cages at Clarksville in 1949.

Insecticide	Pounds to 100 Gallons	Per Cent Dead
Parathion	.25	100
Chlordane	1	100
γ-benzene hexachloride	.30	83
Toxaphene—Sulfur 5 pounds	2	83
Toxaphene	2	75
Lead arsenate	6	75
Lead arsenate	4	62
Lead arsenate and DDT	2 + 1	62
Lead arsenate	3	58
γ-benzene hexachloride	.18	47
Lead arsenate	2	32
Check	—	12
Least significant difference at	.05	26

lead arsenate at 2 lbs. to 100 gallons were significantly better than the check.

The treatments made on May 12 killed an average of 77 per cent of the curculios. This was significantly better than the average mortality of 64 per cent for April 1 and 56 per cent for April 21. The figure for April 1 is not significantly different from that for April 21. The lead arsenate treatments accounted for nearly all the increased toxicity on May 12. Presumably, lead arsenate was more effective on the latter date due to higher temperatures prevailing during this time. Field observations also indicate that lead arsenate is more effective during warm weather.

Additional tests were made on May 25 in the manner indicated above. These tests were unreplicated and only 20 beetles were used in each treatment. The results are given in table 2.

Table 2.—Per cent of adult curculios dead after being caged 9 days on trees sprayed with insecticides on May 25, 1949.

Material	Pounds to 100 Gallons	Per Cent
Dieldrin	.12	100
Aldrin	.12	65
DDT	2	45
DDT and lead arsenate	2 + 2	80
DDT	4	35
Check	—	30

It appeared that dieldrin was effective even at a dosage of 0.12 pound to 100 gallons whereas aldrin at the same dosage was considerably less effective. DDT seemed to have little toxicity to curculios even at high dosages. The mortality in the check is presumably due to natural causes.

Another series of sprays was applied on June 1. A mortality of 60 per cent occurred in the check cages after 14 days, presumably due to natural mortality of overwintered adults. These results are not included.

A final series of sprays was applied on June 16. The beetles used in these tests were presumed to be primarily first generation adults since there was no mortality in the check cages after one week. The results are given in table 3.

Table 3.—Immediate and residual toxicity of various insecticides to adult curculios caged on sprayed trees at Clarksville June 16, 1949.

Material	Lbs. to 100 Gals.	Caged June 16 Per Cent Dead 4 Days	Caged June 29 Per Cent Dead 7 Days
Aldrin	0.25	95	75
Dieldrin	0.25	100	90
Lead arsenate	2.0	10[1]	—
Parathion (no zinc-lime)	0.25	100	25
Parathion	0.25	100	10
Chlordane (no zinc-lime)	1	100	40
Chlordane	1	90	25
Check	—	0	0

[1] This gave 100 per cent kill after 11 days but check rose to 65 per cent.

All the materials gave good results when beetles were caged the day the sprays were applied. However, when beetles were caged 13 days after spraying, dieldrin, and aldrin gave fair results with the former the better of the two. Parathion showed very little toxicity to plum curculio 13 days after application with chlordane not much better. Use of zinc-lime may have decreased effectiveness of parathion and chlordane slightly.

Some of the data obtained are not included in the tables. In the tests on April 1 and 21 TDE was used at 1 and 2 pounds to 100 gallons of water. The number of dead beetles in these cages was essentially the same as the check. On April 21 and May 12 aldrin at 4 ounces to 100 gallons was used and gave 100 per cent mortality in 12 days and 6 days. Dieldrin at 4 ounces to 100 gallons gave 100 per cent mortality in 4 days on May 12. On April 21 benzene hexachloride at 3 pounds of

6 per cent gamma to 100 gallons with no zinc-lime was used. A mortality of 60 per cent was obtained in 12 days as compared to 40 per cent where zinc-lime was used with benzene hexachloride.

Additional beetles were caged on some treated trees 1 week after the trees had been sprayed on May 12. After 12 days the numbers of beetles killed were: Dieldrin 60 per cent, aldrin 35 per cent, chlordane 20 per cent, parathion 10 per cent, and check 10 per cent.

RESULTS 1950.—In 1950 the procedure was the same as in 1949 except that the single tree plots were arranged in a randomized block with 4 replicates. The sprays were applied on April 12 and the beetles caged on April 13. Counts were made on April 7 and April 26. The results are given in table 4.

Table 4.—Mortality of adult plum curculio caged on trees sprayed with different insecticides, at Clarksville on April 12, 1950.

MATERIAL	LBS. TO 100 GAL.	PER CENT	
		4 Days	13 Days
Dieldrin	.25	75	100
Parathion[1]	.25	67	82
Benzene hexachloride (6% gamma)	.24	57	87
Check	—	45	72
Lead Arsenate	2	40	85
Benzene hexachloride (12% gamma)	.24	37	75
Aldrin	.25	32	92
Lead arsenate-sticker	2	32	60
Chlordane	1	22	80
Least significant difference at .05		32	17

[1]Applied April 11.

Due to the high mortality in the check the results lose much of their value. Dieldrin appears to be the most effective material. The addition of a sticker to lead arsenate seems to have decreased its effectiveness.

A second series of sprays was applied on April 19 and 20. Beetles were caged on the trees on April 21. The treatments and the results are given in table 5.

The mortality in the check is again higher than had been anticipated. Dieldrin again appears to be the most effective material used.

A third series of sprays was applied on May 3. Beetles were caged on the trees the same day. Five pounds of wettable sulphur to 100 gallons was included in all sprays. The materials used and the results are given in table 6.

Table 5.—Mortality of plum curculio adults caged on trees sprayed with different insecticides at Clarksville April 19 and 20, 1950.

MATERIAL	LBS. TO 100 GAL.	PER CENT DEAD AFTER 5 DAYS
Dieldrin	0.25	100
Dieldrin	0.12	92
Dieldrin	0.12	87
Lead arsenate	2	
γ-benzene hexachloride	0.48	86
Aldrin	0.25	74
Parathion	0.25	71
γ-benzene hexachloride	0.24	67
γ-benzene hexachloride	0.36	59
Chlordane	1	54
Lead arsenate	2	49
γ-benzene hexachloride	0.24	
Check	—	30
Lead arsenate	2	24
Least significant difference at .05		25

As in previous tests dieldrin proved to be very effective against curculio adults. Methoxychlor also gave excellent results. High dosages of benzene hexachloride did not prove too effective under the conditions of these tests. Lead arsenate, although relatively much better on the last count than in the earlier ones, was only moderately effective.

Additional beetles were caged on the trees of 4 treatments on May 10 *i.e.*, 1 week after the sprays were applied. Counts were made on May 24, two weeks later. The results are given in table 7. There is no significant difference between dieldrin, lead arsenate, and methoxychlor in this test. However, they were all

Table 6.—Mortality of adult curculios after being caged on peach trees sprayed with various insecticides at Clarksville on May 3.

MATERIAL	LBS. TO 100 GAL.	PER CENT DEAD AFTER			
		3 Days	6 Days	12 Days	21 Days
Methoxychlor	2	72	92	92	95
Dieldrin	0.25	70	100	100	100
Parathion	0.25	51	71	78	78
Benzene hexachloride (12% gamma)	0.48	23	36	42	65
Chlordane	1.0	20	46	61	70
Benzene hexachloride (6% gamma)	0.48	20	26	55	55
Aldrin	0.25	15	28	35	60
Benzene hexachloride (6% gamma)	0.24	15	26	39	57
Lead arsenate	2	9	10	39	77
Check	—	0	5	5	25
Least significant difference at	0.05	28	35	30	32

moderately effective and are significantly better than the check.

Table 7.—Per cent mortality of adult curculios caged 2 weeks on trees sprayed with different insecticides.

Material	Lbs. to 100 Gal.	Per Cent Dead
Methoxychlor	4	82
Lead arsenate	2	82
Dieldrin	0.25	80
Check	—	17
Least significant difference at .05		17

A fourth series of sprays was applied on May 17 and 19. Beetles were not caged on these trees until May 24 and 25.

The materials used and the results are given in table 8.

When the first count was made the sprays containing methoxychlor and dieldrin showed considerable toxicity, but none of the other materials did. At the time of the second count nearly all the materials gave fair to good results. In this experiment DDT does not seem to have increased the effectiveness of lead arsenate. Methoxychlor at 2 pounds (50 per cent wettable) gave as good results as double that amount. None of the insecticides used either year showed any visible injury to peach trees or fruit.

SUMMARY.—Cage tests were conducted in 1949 and 1950 at Clarksville to compare effectiveness of various insecticides with lead arsenate for plum curculio control on peaches. Lead arsenate is toxic to plum curculio, but acts slowly, especially during cool weather, and may injure the trees under certain conditions. Methoxychlor, dieldrin, and parathion were all highly toxic to plum curculio adults. Less effective were chlordane, aldrin, benzene hexachloride and toxaphene. DDT and TDE were ineffective. Addition of DDT did not consistently increase effectiveness of lead arsenate. The use of a sticker with lead arsenate appeared to decrease its effectiveness. Methoxychlor and dieldrin appeared to have considerable residual toxicity to plum curculio, but parathion did not.

The use of zinc-sulfate-lime seemed to decrease slightly the effectiveness of chlordane, benzene hexachloride, and parathion.

No damage to the fruit or foliage resulted from the use of any of the materials in these tests.

Table 8.—Mortality of plum curculio adults caged several days after trees were sprayed with different insecticides at Clarksville May 17 and 19, 1950.

Material	Lbs. to 100 Gal.	Per Cent Dead	
		5–6 Days	12–13 Days
Methoxychlor	2.0	85	85
Methoxychlor DDT	1.5 1.0	85	92
Methoxychlor	1.0	74	87
Methoxychlor Lead arsenate	1.5 2	67	72
Dieldrin	.25	63	70
Lead arsenate DDT	2 1	24	70
Chlordane	1.0	13	70
Chlordane DDT	1.0 1.0	12	47
Check	—	12	37
Chlordane	1.0	10	85
Parathion	.25	8	68
Lead arsenate	2	8	77
Least significant difference	.05	22	28

White Grub Control in Strawberries

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Strawberry production in Indiana has seldom, if ever, been high enough to meet the demand. The crop is quickly perishable and this results in scarcity at points distant from production areas. The necessity of a large amount of hand labor contributes heavily to small acreage and scarcity. Low per acreage production of

high quality fruit also plays its part. Accordingly, if through more efficient insect control the per acre production can be increased, this crop may become more attractive and profitable.

Studies made in the past have shown that the establishment of berry patches on new ground is one way of increasing the per acre production with a minimum of complications. To use new ground and get high production, it has been necessary to eliminate white grubs. To do this, the procedure recommended has been, to plow up sod or woodland in August, grow a cultivated row crop the following year, and set to berries the third year. The weakness to this production technique is that but few growers plan 4 years in advance to pick a new patch of berries.

The primary purpose of this study has been to find a material which will kill white grubs in new land to be used for strawberries, at the same time retain the high production capacity inherent in new soil, and to do this without incorporating into the soil objectionable residue. By accomplishing this purpose there will be eliminated the necessity of beginning to prepare new land two seasons before setting berry plants. With this in mind, several chemical soil treatments have been studied, but no major effort has been made to try to compare all the fine points of one with the other, and so eliminate some of the treatments.

The data given in table 1 are results of studies made over a 3-year period. The first year's work was of a preliminary nature. Early in 1949 Fred Fletcher, of the Dow Chemical Company, released, "A Partial Summary of Soil Insecticides and Fumigants, and Their Uses."As the result (from this list of 23 materials and combinations) four different soil treatments, those which seemed most applicable to strawberries, were chosen for study. It goes without saying that most of the soil insecticides used in this study, killed the white grubs in the soil, inasmuch as each of the chemicals listed by Fletcher had already been proven affective in eliminating certain soil insects. However, with strawberries as the specific crop to be studied, there are several problems peculiar to them requiring a solution. The efficiency of white grub kill is one, a possible reduction in the yield as the result of use of the chemical on the soil is another, and still another is the possibility of the accumulation of an objectionable residue in the soil.

Before treating and setting berry patches, the white grub population of the soil to be used, was determined. This was done by spading up the sod to a depth of a foot and by carefully crumbling the soil to find and count the grubs.

One set of plots was instituted each year for 3 years. In 1948 eight plots of two varieties each, were laid out, treated, and set to berries. This series contained three replications of the lead arsenate treatment, three of chlordane and two checks. At the time of setting, digging showed this woodland-border site contained as many as 28 grubs per square yard of turf. In 1949 plots numbered 17. They were randomized and 0.08 acre in size. Aroma and Premier were the varieties used, and these were set in parallel rows, five rows wide, and 17 plots long. At the time of the setting, the white grub population was determined to be 16 per square yard of this pasture-land turf. The 1950 plantings were of Aroma for observation in connection with the benzene hexachloride treatment as the result of excellent performance of the variety in similar tests. A plot 15 feet square was treated with benzene hexachloride and set to berries while an adjacent one of the same size was laid out for the purpose of population counts. Here the white grubs averaged seven per square yard in this heavy woodland-border sod.

Studies may prove that the use of certain soil insecticides will be more satisfactory when they are applied to sod before plowing it under, and that others will do better when applied to the plowed ground and disced well into the soil. In this study, benzene hexachloride has been used both ways with satisfactory results. Chlordane was used by applying it to the sod immediately before plowing, after which the ground was worked down immediately.

To obtain the production records making up the table for the 1950 crop, 14,552 berries were harvested. Each of the 15 picking days the berries from each of the plots were picked and counted separately. After picking started, not more than 2 days elapsed between pickings in any instance. The berries were graded in U.S. No. 1's and off-grades each time the

Table 1.—Crates per acre—1950 strawberry crop.

Soil Treatment Pounds per Acre	Premier		Aroma	
	U.S. No. 1	Off Grades	U.S. No. 1	Off Grades
24.5 Chlordane (40%) 7.5 DDT 50% wp 15.12 BHC of 12% gamma	257.13	26.47	403.00	12.35
30.2 BHC 12% gamma	271.75	32.01	375.10	16.39
435 L. Arsen.	291.16	32.01	372.83	15.13
Untreated check	214.27	30.25	354.43	15.13
	119.33	12.96	215.15	8.51

Figures in this table represent the total crop produced and include small seedy and rotting fruit. For this reason the per acre figures are higher than most commercial growers record.

plots were picked throughout the season which began on May 29 and lasted through June 16. In order to express the number of berries as quarts and in this manner state the per acre production, a count was made of each variety each picking day to determine the average number of berries per quart box for each plot and variety. This number was then used as the divisor, the total number of berries from the plot as the dividend, and the quotient represented the number of quart boxes for the plot that picking day. As a typical example of the change in berry size throughout the season, in one instance in which 13 pickings were made during the 15-day picking season, the number of Aroma berries per quart for each picking averaged as follows: 51, 65, 77, 55, 65, 88, 84, 69, 92, 100, 111, 130, and 135.

Lead arsenate has been recommended for use in controlling white grubs in strawberries for many years. Success through its use is found to depend upon the manner in which it is incorporated with the soil. Unless it is worked into the soil very thoroughly indeed, the newly set berry plants have difficulty in becoming established. Lead arsenate persists in the soil over a long period, and it is very expensive to use. These features are not in its favor.

Chlordane was used for the first time to rid the soil of white grubs in the plots set in 1948. The per acre cost for the treatment is not prohibitive and its performance the first year was only promising. In the more comprehensive 1949 set of plots, chlordane did not show up well from a production standpoint in Premier plots, though it was the best on Aroma.

Benzene hexachloride was used in combination with DDT, and alone. The addition of DDT to benzene hexachloride did not result in an improvement in berry production. Furthermore, DDT is known to be accumulative in the soil. Accordingly there seems to be no reason for using it to rid the soil of white grubs. Though it is not yet known just how long benzene hexachloride persists in soil when used alone, it performed well. Production of plots of Premier treated with benzene hexachloride, was the highest of any of the treatments on that variety, and Aroma treated with this material was exceeded by chlordane only. All things considered, it would seem as though benzene hexachloride is a most promising material for use to eliminate white grubs. In both 1949 and 1950 inspections were made every few days of recently treated benzene hexachloride plots to determine the kind of insects killed. These inspections were made over a 6 weeks' period after treatment in 1950. Based on the number of dead and dying insects found, the greatest kill occurred approximately three weeks after treatment. As an example, in one area set to Aroma the grub population, determined by digging, was found to be not less than seven per square yard. The third week after treatment, on a per acre basis, dead dung beetles on the surface of the plowed, treated, and disced soil, averaged around 3000. Ground beetles of three species numbered slightly less. In the upper foot of soil, a large number of dead and moribund ground beetle larvae were found. This was also true of centipedes. Apparently the smaller white grub larvae succumb to the treatment first. Three weeks after the ground was plowed, treated, and worked down, soil examinations revealed that only the white grub larvae approximating maturity, remained alive. The smaller sized ones when found, were dead, much shortened and shrunken, though they still retained a fairly normal color. Diggings made a month or more after the soil was treated, revealed no white grub larvae and it was assumed that by this time, most of them had deteriorated beyond the point of recognition.

Though more fundamental research is

desirable in a problem of this kind, one of the most important objectives, before suggesting the practice to berry growers for use, is to develop control measures which can be practically and economically applied. The application of the treatments used in this study offers no problems once the output per unit of time has been determined for the sprayer or duster to be used. The economy of the various treatments is evident after the cost of each has been computed. The cost per acre has been figured out for the materials and amounts suggested in (1) the Fletcher summary and (2) those found to be satisfactory in this experiment. The considerable variation between the per acre cost of 1 and 2 is explainable. The amounts of materials used in Fletcher's summary of soil treatments to control white grubs reflects the findings in Japanese beetle control studies. More recently it has been found that more soil insecticide is needed to kill some species of white grubs than is needed for Japanese beetles. The following items give the comparative costs of each of the four soil treatments in amounts suggested by Fletcher's summary and as found satisfactory in this study. In determining these figures the unit price used was that charged to growers during the spring of 1950 when the materials were purchased in 100 pound lots. The per acre cost of:

1. Benzene hexachloride and DDT—Fletcher's summary	$ 1.32
1a. Benzene hexachloride and DDT—as used in this experiment	8.44
2. Benzene hexachloride alone—Fletcher's summary:	
A. 100 lbs. of 5 per cent gamma isomer	1.71
B. 4 to 8 lbs. gamma isomer when a 12 per cent wettable powder is used	$13.65 to $27.30
2a. Benzene hexachloride alone—as used in this experiment	15.10
3. Chlordane alone—Fletcher's summary	5.30
3a. Chlordane alone—as used in this experiment	12.98
4. Lead arsenate alone—Fletcher's summary	121.96
4a. Lead arsenate alone—as used in this experiment	121.96

That the practicability of white grub control has been improved is evident, for until recently lead arsenate was the most often recommended soil treatment for the control of white grubs.

SUMMARY.—From the studies of three different sets of field plots located several miles apart, some conclusions may be drawn with respect to the effectiveness of white grub control in berry patches through the use of the four chemicals under test. The lead arsenate treatment always resulted in poorer crops of berries than that of any of the other chemically treated plots. In all except preliminary studies the untreated check plots were lowest in production. Although the total production was less, the untreated check plots of both Premier and Aroma produced a larger percentage of U.S. No. 1 berries than any of the treated plots. Though this fact may be worth noting from the standpoint of the research man it is of no value to the commercial berry producer. Since neither Aroma or Premier reached first place in the plots which received the benzene hexachloride-DDT combination and inasmuch as DDT is known to persist in the soil for a long time, it would seem that either chlordane or benzene hexachloride is to be preferred. Chlordane failed to perform well in the 1948 experiment and with Premier in the 1949 experiment, though it did very well when used with Aroma. Benzene hexachloride was consistently good. It can be applied to the sod before plowing or to the surface of the freshly plowed ground and worked into the soil by discing. Soil examinations show that benzene hexachloride kills the greatest number of insects about 3 weeks after the soil is treated. Though John Shread of the Connecticut Agricultural Experiment Station and others have shown that somewhat higher dosages than were used are needed to kill all instars of white grubs, it does not necessarily follow that the dosages used will not accomplish satisfactory results in soils to be used for strawberries.

In the work during which these counts were made, benzene hexachloride and the other treatments used were applied to the freshly plowed ground one day, the soil was thoroughly worked down by discing the same day, the berries were set the following day, and the following spring some plots so-treated, produced as many as 415.35 crates of 24 quarts each of Aroma per acre. The cost of each of the treatments is low enough to be inconsequential except in the case of lead arsenate.

Studies with Acaricides for Control of Mites in Apple and Pear Orchards in Southern California[1]

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The continued use of DDT sprays for control of codling moth in apple and pear orchards in southern California has been accompanied by the development of injurious populations of several species of mites which were usually of little importance or were not known as factors in the production of these fruits in this area prior to the use of DDT.

Mite species found on apple trees include the two-spotted spider mite, *Tetranychus bimaculatus* Harvey; the closely related species *Tetranychus multisetis* McG.; the Pacific mite, *Tetranychus pacificus* McG.; *Tetranychus mcdanieli* McG.; the European red mite, *Paratetranychus pilosus* (C. & F.); and the clover mite, *Bryobia praetiosa* Koch.

In pear orchards the Pacific mite and the clover mite have increased with the use of DDT, and where certain types of orchard cover are present the two-spotted spider mite has become a serious problem.

This paper presents the principal results obtained in orchard studies from 1947 through 1950 with 18 candidate acaricides for control of the two-spotted spider mite, the European red mite, and the clover mite on apple trees, and the Pacific mite and two-spotted spider mite on pear trees.

Acaricides may afford protection (1) by causing initial mortality of one or more of the developmental stages of the mites present at the time of application; (2) by providing a lasting residue on the plant surface, which is toxic to one or more developmental stages and gradually reduces the mite population; (3) by their absorption by the plant tissues, so that these become toxic; or (4) by a combination of these effects. Field experimentation does not permit complete elucidation of the manner in which acaricides function, but some observations were made on this question.

MATERIALS AND METHODS.—The following acaricides were used in these studies:

1. Dicyclohexylamine dinitro-*o*-cyclohexylphenate[4]
2. Parathion
3. Ethyl-*p*-nitrophenyl thionobenzenephosphonate (EPN)
4. Octamethyl pyrophosphoramide (OMPA)
5. 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate (Compound 3901)
6. S-carbamylmethyl-0,0-dimethyl dithiophosphate (Compound 3869)
7. S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate (Compound 4049)
8. S-(1,2-dicarbethoxyethyl)-0,0-diethyl dithiophosphate (Compound 3975)
9. S-(1,2-dicarbomethoxyethyl)-0,0-diethyl dithiophosphate (Compound 4018)
10. 0-(2-chloro-4-nitrophenyl)-0,0-dimethyl dithiophosphate (Compound 4124)
11. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite (Compound 88R)
12. *p*-Chlorophenyl-*p*-chlorobenzenesulfonate (Compound K-6451)
13. 2,4-Dichlorophenylbenzenesulfonate (Compound 923)
14. *p*-Chlorophenyl phenylsulfone (Compound R-242)
15. Bis-(*p*-chlorophenyl)-methylcarbinol (DMC)
16. Bis-(*p*-chlorophenoxy)-methane (Compound K-1875)
17. 1,1-Bis-(x-chlorophenyl)-ethane (Compound K-3926)
18. Lorol-2-thiazolinyl sulfide (IN-4200)

Parathion and dicyclohexylamine dinitro-*o*-cyclohexylphenate were used separately as standard treatments. To obtain

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[4] *DN-111.*

information on the relative effectiveness of acaricides against two or three species, sprays were applied in some instances against multispecific mite populations. Four weeks was selected as the minimum period during which a summer application of a given dosage of a candidate compound should afford protection from mite infestation. This interval is the one ordinarily employed in the application of DDT cover sprays for codling moth in this area. The interval between mite control sprays may be extended in orchards where the codling moth has been controlled by first-brood sprays; some trials were conducted with intervals of as much as seven weeks between acaricidal applications.

To compare their relative effectiveness in preventive schedules (those in which the timing of the initial application is essentially preventive), acaricides were usually included in the second and third regularly scheduled DDT cover sprays for codling moth control. Corrective sprays were applied against relatively high mite populations at various times during the season, either in combination with DDT cover sprays or as special acaricidal sprays.

Dosages of materials employed in the orchard trials are expressed as the amount of active ingredient for 100 gallons of water. Unless otherwise indicated, full-coverage applications were made. Equipment used included conventional types of high-pressure sprayers with manually operated guns or rotary or fixed-nozzle vertical booms, and an air-blast sprayer.[5]

Samples for mite counts in multispecific infestations on apple trees were taken by selecting 10 fruit-spur leaves from the inside and 10 from the outside of each of five trees, for a total of 100 leaves. These samples were refrigerated from the time of collection and were later examined under a stereoscopic microscope. For trials with the clover mite only, counts were made on 10 leaves from each of five trees, or on a total of 50 leaves selected in the manner described above and examined with head-piece binoculars in the field.

Population data for the two-spotted spider mite, European red mite, and clover mite are presented in terms of immature and adult mites or in terms of eggs per 100 leaves. In trials of preventive sprays results are also expressed in terms of percentage reduction as compared with check-tree populations. For corrective sprays, these data are given in terms of percentage reduction of the original populations. In comparisons of preventive sprays, the possibly misleading factor of a natural reduction in mite populations because of seasonal cycles was offset by making counts at a time when the populations were at a high level on the check trees.

Pacific mite injury to Bartlett pear trees in this area usually develops from relatively low populations, four or five mites per leaf being enough to cause severe injury. The mite population is unevenly distributed on the tree. Usually, within 2 or 3 weeks after the first leaf discoloration is noted the originally infested areas on the tree are defoliated. At this time mite populations may be exceedingly low and mite counts or population density ratings impracticable. In early trials Pacific mite injury was determined by counting the number of injured leaves falling into five field boxes placed beneath each count tree. When plots are replicated sufficiently, this method, though time consuming, provides useful objective data.

The need for a more rapid method led to the development of a rating system. In a trial involving 10 single-tree replicates of seven treatments (Table 5), leaf-fall counts were made as described above; each tree was also assigned a numerical rating according to the estimated degree of defoliation caused by Pacific mites. From a comparison of the two systems of estimating mite injury, it is evident that so far as the ranking of treatments is concerned the two systems are well correlated. The rating system was employed in trials for Pacific mite control subsequent to 1947; it was also employed in trials with two-spotted spider mite, which also causes premature defoliation of Bartlett pear trees. Such a rating system provides apparently reliable information as to the comparative status of the plots within a given orchard at the time the ratings are made. Observations have indicated, however, that it does not provide a reliable index to the progressive seasonal defoliation caused by mite infestation in a given plot. This is because the rating supplied

[5] A model 36 Speed Sprayer was made available through the courtesy of the Bean-Cutler Division of the Food Machinery Corporation.

Table 1.—Effect of preventive applications of various acaricides for control of two-spotted spider mite, European red mite, and clover mite on Delicious apple trees in an orchard near Oak View, Ventura County, California, 1948.[1]

Treatment No., Material[2] and Formulation[3]	Active Ingredient per 100 Gal.	Schedule of Applications	Two-Spotted Spider Mite		European Red Mite		Clover Mite	
			Average No. per 100 Leaves (Aug. 4)	Per Cent Reduction (Compared with Check)	Average No. per 100 Leaves (Aug. 4)	Per Cent Reduction (Compared with Check)	Average No. per 100 Leaves (Aug. 4)	Per Cent Reduction (Compared with Check)
1. DDT only (check)	—	—	3,715	—	1,160	—	378	—
2. Parathion 25-W	1 oz.	6/4, 7/1	1,608	57	174	85	43	89
3. Parathion 25-W	1 oz.	6/4	1,426	62	570	51	74	80
4. Parathion 25-W	2 oz.	6/4, 7/1	115	97	127	89	5	99
5. Parathion 25-W	2 oz.	6/4	394	89	437	62	36	90
6. Parathion 25-W	4 oz.	6/4, 7/1	86	98	20	98	1	99
7. Parathion 25-W	4 oz.	6/4	348	91	55	95	36	90
8. Parathion 25-W	2 oz.	5/7, 6/4, 7/1	73	98	92	92	18	95
9. Bis-(*p*-chlorophenoxy)-methane 40-W	8 oz.	6/4, 7/1	172	95	40	97	588	+55
10. Bis-(*p*-chlorophenoxy)-methane 40-W	16 oz.	6/4, 7/1	33	99	23	98	398	+5
11. 1,1-Bis-(x-chlorophenyl)-ethane 98-E	1 pt.	6/4, 7/1	231	94	677	42	112	70
12. 1,1-Bis-(x-chlorophenyl)-ethane 98-E	1 qt.	6/4, 7/1	141	96	514	56	131	65
13. Bis-(*p*-chlorophenyl)-methylcarbinol 25-E	4 oz.	6/4, 7/1	2	99	23	98	3	99
14. Bis-(*p*-chlorophenyl)-methylcarbinol 25-E	8 oz.	6/4, 7/1	3	99	3	99	1	99
15. Lorol-2-thiazolinyl sulfide 75-E	0.375 pt.	6/4, 7/1	345	91	58	95	175	54
16. Lorol-2-thiazolinyl sulfide 75-E	0.75 pt.[4]	6/4, 7/1	116	97	13	99	3	99
17. Dicyclohexylamine dinitro-*o*-cyclohexylphenate 20-W	2.4 oz.	6/4, 7/1	576	84	1,387	+20	0	100

[1] Sprays applied to single-tree plots replicated six times, using conventional equipment and ground leads.
[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal., except in treatment 8.
[3] In percentage wettable powder (W) or emulsifiable solution (E).
[4] For application of July 1, the amount of active ingredient was increased to 1.5 pt. per 100 gal.

by a given observer for a given amount of defoliation may vary in the course of the season as the general level of defoliation increases. Newcomer & Dean (1946) employed a rating system which was based upon mite population densities and was reliable in this respect.

When single-tree plots were used, sprays were applied to plots replicated in 5 to 15 randomized blocks. In other trials single or duplicate plots were used, each 25 to 40 yards in width and containing 16 to 300 trees. The extent of replication was restricted in some trials by the use of the mechanical applicators previously described. A satisfactory degree of plot integrity, so far as drift is concerned, was attained by spraying during relatively calm periods, and, when mechanical applicators were used, by spraying the outer halves of border rows with one-side delivery. That the intended results were achieved is attested in part by the clear-cut plot boundaries which were apparent when an inferior treatment or schedule was adjacent to a superior one.

Results.—In interpreting the results of these trials several conditions under which they were conducted should be recognized. Higher temperatures generally prevail in the Antelope Valley, where the pear orchard experiments were located, than in the various districts in which the apple orchard trials were conducted. This may account for the shorter interval of protection afforded by relatively volatile materials in the pear orchard trials.

Experiments on apple trees for control of the two-spotted spider mite were conducted in orchards in which there was no reinfestation from a cover crop, the use of herbicidal sprays by the grower having eliminated this problem. These trials were also directed against European red mite, and they followed application of a 3 per cent dormant oil during the dormant period for control of the overwintering eggs of this species.

Experiments on pear trees for control of the Pacific mite were conducted in orchards in which cover-crop growth was sparse and of little importance as a source of mite reinfestation. In contrast, trials for control of two-spotted spider mite on pear trees were located in orchards in which a heavy cover growth was severely

Table 2.—Effect of two preventive applications of various acaricides for control of two-spotted spider mite and European red mite on Delicious apple trees in an orchard near Oak View, Ventura County, California, 1949 and 1950.[1]

Treatment No., Material[2] and Formulation[3]	Active Ingredient per 100 Gal. (Ounces)	Two-Spotted Spider Mite		European Red Mite	
		Average Mites per 100 Leaves	Per Cent Reduction (Compared with Check)	Average Eggs per 100 Leaves	Per Cent Reduction (Compared with Check)
1949 applications June 8 and July 8; counts made on August 10					
1. DDT only (check) —	—	>3,000	—	>4,000	—
2. Parathion 25-W	2	504	83	400	90
3. Parathion 25-W	3	411	86	154	96
4. 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate 25-W	2	57	98	2	99
5. 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate 25-W	3	16	99	0	100
6. S-carbamylmethyl-0,0-dimethyl dithiophosphate 25-W	2	142	95	326	91
7. S-carbamylmethyl-0,0-dimethyl dithiophosphate 25-W	3	176	94	14	99
8. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	1.8	346	88	35	99
9. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	3	13	99	10	99
10. *p*-Chlorophenyl-*p*-chlorobenzene-sulfonate 50-W	4	286	90	104	97
11. *p*-Chlorophenyl-*p*-chlorobenzene-sulfonate 50-W	8	97	96	591	85
12. 2,4-Dichlorophenylbenzenesulfonate 25-W	3	>3,000	—	—	—
13. 2,4-Dichlorophenylbenzenesulfonate 25-W	6	>3,000	—	—	—[4]
14. Bis-(*p*-chlorophenyl)-methyl-carbinol 25-E	4	13	99	5	99
15. Bis-(*p*-chlorophenyl)-methyl-carbinol 25-E	6	6	99	0	100
16. Bis-(*p*-chlorophenyl)-methyl-carbinol 25-E	6[5]	255	91	121	97
17. Bis-(*p*-chlorophenyl)-methyl-carbinol 25-W	4	37	98	5	99
1950 applications June 21 and August 8; counts made July 19 and Sept. 11[6]					
1. DDT only (check) —	—	5,875	—	4,814	—
2. Parathion 25-W	3	603	90	293	94
3. Ethyl-*p*-nitrophenyl thionobenzene-phosphonate 27-W	3.2	565	90	2	99
4. Octamethyl pyrophosphoramide Tech.	9	45	99	115	98
5. S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate 16-W	2[7]	705	88	347	93
6. S-(1,2-dicarbethoxyethyl)-0,0-diethyl dithiophosphate 48-E	3[8]	605	90	85	98
7. S-(1,2-dicarbomethoxyethyl)-0,0-diethyl dithiophosphate 47.7-E	3	399	93	47	99
8. 0-(2-chloro-4-nitrophenyl)-0,0-dimethyl dithiophosphate 25-E	3	4,064	31	2,636	45
9. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	3.6	52	99	16	99
10. *p*-Chlorophenyl-*p*-chlorobenzene-sulfonate 50-W	16	43	99	522	89
11. *p*-Chlorophenyl phenylsulfone 50-W	24	255	96	29	99

[1] Sprays applied to single-tree plots replicated in six blocks in 1949 and in five blocks in 1950, using conventional equipment and ground leads.
[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal.
[3] In percentage wettable powder (W) or emulsifiable solution (E).
[4] Counts made July 7 indicated 97 per cent reduction.
[5] One application only, on June 8.
[6] Analyses of triplicate samples of 30 fruits each (6 fruits from each of 5 trees) at harvest (September 11) showed surface residues of 0.09 p.p.m. EPN from treatment 3, and residues of 0.48 p.p.m. of compound 88R from treatment 9.
[7] In treatment 5, the amount of active ingredient was increased to 2.6 ounces at the time of the second application, August 8.
[8] In treatments 6 to 8, the amount of active ingredient was increased to 4 ounces at the time of the second application, August 8.

infested and provided a potentially continuous source of reinfestation.

Parathion.—Wettable powder formulations containing either 15 or 25 per cent parathion were used. Data on control of two-spotted spider mite and European red mite on Delicious apple trees are presented in tables 1 and 2. Results of 10 varied schedules applied in preventive programs in coexisting infestations give no indication of specificity of action by parathion in the control of these species in the absence of reinfestation from a cover crop by the former species. The

Table 3.—Effect of corrective applications of various acaricides for control of clover mite on Delicious apple trees in an orchard near Oak View, Ventura County, in 1948 (Series A), and in an orchard at Julian, San Diego County, in 1949 (Series B).

Treatment No., Material[1] and Formulation[2]	Active Ingredient per 100 Gal.	Average Mites per 100 Leaves		Per Cent Reduction Population
		Pre-treatment Count	Post-treatment Count	
Series A—Spray applied 7/5/48[3]		7/1/48	8/4/48	
1. Parathion 25-W	2 oz.	1920	263	86
2. Lorol-2-thiazolinyl sulfide 75-E	0.375 pt.	3528	1136	68
3. Lorol-2-thiazolinyl sulfide 75-E	0.75 pt.	3528	797	77
4. Dicyclohexylamine dinitro-*o*-cyclohexylphenate 20-W	2.4 oz	2856	191	93
Series B—Spray applied 6/30/49[4]		6/30/49	7/21/49	
1. DDT only (check)	—	450	2500	555
2. Parathion 25-W	2 oz.	1200	900	25
3. Parathion 25-W	3 oz.	1200	250	79
4. Ethyl-*p*-nitrophenyl thionobenzene-phosphonate 27-W	1.7 oz.	1200	350	71
5. Ethyl-*p*-nitrophenyl thionobenzene-phosphonate 27-W	2.6 oz.	1200	<100	>92
6. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	3 oz.	320	275	14
7. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	4.2 oz.	320	<50	>84
8. *p*-Chlorophenyl-*p*-chlorobenezene-sulfonate 50-W	8 oz.	450	<50	>89
9. *p*-Chlorophenyl-*p*-chlorobenzene-sulfonate 50-W	16 oz.	450	0	100
10. 2,4-Dichlorophenylbenzenesulfonate 25-W	8 oz.	1200	<50	>96
11. 2,4-Dichlorophenylbenzenesulfonate 50-E	16 oz.	1200	<50	>96

[1] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal.
[2] In percentage wettable powder (W) or emulsifiable solution (E).
[3] Applications made with speed sprayer to unreplicated plots 40 yards wide.
[4] Applications made with conventional equipment and ground leads to unreplicated plots of 10 trees each.

average reduction for the ten schedules, as compared with check-tree populations, was 85 per cent for both two-spotted spider mite and European red mite.

In preventive applications for control of clover mite, an average reduction of 92 per cent was obtained in the eight parathion schedules described in tables 1 and 4. Parathion appears to be less effective as a corrective spray than as a preventive spray for clover mite, the three corrective trials with parathion (Table 3) averaging 63 per cent reduction.

Following application of dormant oil against European red mite eggs, it is indicated that at least two, and in some cases three, sprays of 3 ounces of parathion at intervals of 4 weeks will be required in preventive programs for commercial control of coexisting infestations of European red mite and two-spotted spider mite on apples in this area. For clover mite control on apples, parathion is best employed as a preventive spray, and one or two applications of 2 ounces of parathion are indicated.

Trials for control of mites on Bartlett pear trees are reported in tables 5 to 9. An initial trial for control of Pacific mite with parathion was carried out in 1947. Two sprays of 0.6-ounce dosage of this compound failed to provide adequate protection from infestation; sprays of 1.2 and 2.4 ounces offered considerable promise. Subsequently, as indicated in table 6, it was determined that a single preventive application of a 3-ounce dosage is inadequate for seasonal protection against Pacific mite. Similarly, two applications of 3 ounces for parathion applied as alternate sprays with DDT (schedule 3, Table 7) did not provide adequate control. These results may be compared with those of schedule 1 (Table 7), which differed in

Table 4.—Effect of single preventive applications of various acaricides for control of clover mite on Delicious apple trees in an orchard near Wrightwood, San Bernardino County, California, 1950.[1]

Treatment No., Material and Formulation[2] Applied April 11 (Pink Stage)		Active Ingredient per 100 Gal. in Ounces	Average No. of Mites per 100 Leaves[3] July 10	Per Cent Reduction in Mite Population (Compared with Check)
1. Check (unsprayed)	—	—	752[4]	—
2. Parathion	25-W	3	22	97
3. Ethyl-*p*-nitrophenyl thionobenzene phosphonate	27-W	2	1,150	+53
4. Ethyl-*p*-nitrophenyl thionobenzene phosphonate	27-W	3	416	45
5. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite	13-W[5]	2.1	1,306	+74
6. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite	13-W[5]	3.1	122	84
7. *p*-Chlorophenyl-*p*-chlorobenzene sulfonate	50-W	8	38	95
8. *p*-Chlorophenyl-*p*-chlorobenzene sulfonate	50-W	16	4	99
9. 2,4-Dichlorophenylbenzenesulfonate	50-E	8	4	99
10. 2,4-Dichlorophenylbenzenesulfonate	50-E	12	0	100
11. *p*-Chlorophenyl phenylsulfone	50-W	8	492	35
12. *p*-Chlorophenyl phenylsulfone	50-W	24	8	99
13. Dicyclohexylamine dinitro-*o*-cyclo-hexylphenate	20-W	2.4	2	99

[1] Sprays applied to 4×4 tree plots with conventional equipment, using ground leads. Mite population largely in nymphal stage.
[2] In percentage wettable powder (W) or emulsifiable solution (E).
[3] Counts based on samples of 50 leaves each. Samples taken May 15 showed similar trends, lower populations.
[4] Mite population declining; all leaves severely injured.
[5] This lot of wettable powder differed from others of this compound in percentage of active ingredient.

Table 5.—Correlation between leaf-drop data and visual rating of defoliation caused by Pacific mite injury after two preventive applications of various acaricides on Bartlett pear trees, Antelope Valley, California, 1947.[1]

Treatment No., Material[2] and Formulation[3] Applied June 11 and July 14		Active Ingredient per 100 Gal.	Leaf Drop		Visual Rating of Defoliation	
			Average per Unit Area[4]	Rank	Average[5]	Rank
1. DDT only (check)	—	—	203	7	4.0	7
2. Bis-(*p*-chlorophenoxy)-methane	40-W	8 oz.	81	6	2.4	6
3. Bis-(*p*-chlorophenoxy)-methane (plus spray adjuvant, 5 oz. per 100 gallons)[6]	40-W	8 oz.	52	5	1.6	5
4. 1,1-Bis-(x-chlorophenyl)-ethane	80-E	1 qt.	16	3	0.2	2.5
5. 1,1-Bis-(x-chlorophenyl)-ethane	98-E	1 qt.	15	2	0.1	1
6. 1,1-Bis-(x-chlorophenyl)-ethane	96-E	1 qt.	13	1	0.2	2.5
7. Dicyclohexylamine dinitro-*o*-cyclohexyl-phenate	20-W	2.4 oz.	34	4	1.2	4

[1] Sprays applied to single-tree plots replicated in 10 blocks, using conventional equipment and ground leads.
[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal. water.
[3] In percentage wettable powder (W) or emulsifiable solution (E).
[4] Average leaf drop in sampling area of 7 sq. ft. per tree, July 26 to August 29.
[5] Average of defoliation ratings noted by two observers on each replicate plot: 0 = none, 1 = light, 2 = light-medium, 3 = heavy-medium, 4 = severe, 5 = very severe.
[6] *Colloidal Z-1.*

that the 3-ounce dosage of parathion was applied in successive sprays with an interval of 24 days between sprays and resulted in good control. Sprays applied with a high-pressure boom sprayer at a 50 per cent reduction in volume, although maintaining the same rate of parathion per acre, resulted in inferior mite control, as shown in schedule 2 (Table 7). Preventive programs of two or three successive pre-harvest sprays of a 3-ounce dosage of parathion at intervals of approximately 3 weeks are indicated for commercial control of Pacific mite on Bartlett pear trees in this area.

Data on control of two-spotted spider

Table 6.—Effect of single preventive applications of various acaricides for control of the Pacific mite on Bartlett pear trees, Antelope Valley, California, 1949.[1]

Treatment No. and Material Applied June 20[2]	Formulation[3]	Active Ingredient per 100 Gal., in Ounces	Average Rating[4] of Mite Injury (Defoliation) Sept. 8
1. Parathion	25-W	3.0	4.6
2. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite	15-W	3.6	1.0
3. *p*-Chlorophenyl-*p*-chlorobenzenesulfonate	50-W	8.0	4.2
4. 2,4-Dichlorophenylbenzenesulfonate	25-W	6.0	2.8

[1] Sprays applied with Speed Sprayer to unreplicated plots 25 yards wide.
[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal.
[3] In percentage wettable powder (W).
[4] Average of defoliation ratings noted on 10 trees by two observers: 0 = none, 1 = light, 2 = light-medium, 3 = heavy-medium, 4 = severe, 5 = very severe.

mite on Bartlett pear trees are presented in tables 8 and 9. The control of this species is not adequate when parathion is applied on a preventive or corrective basis at a 3-ounce or 4-ounce dosage at intervals approximating one month. This failure occurred in the presence of a heavily infested orchard cover. A reduced interval would be indicated in attempts to increase the efficiency of this compound.

Correlated studies of parathion residues on apples and pears (Barnes *et al.* 1950) have shown that when parathion is used in a dosage range generally required for foliage sprays, (a) it is not absorbed by the fruit; (b) application three weeks before harvest results in fruit-surface residues at harvest below 0.1 p.p.m.; and (c) low-level surface residues on apples at harvest are not carried over as ultimate residues in cider.

Ethyl-p-nitrophenyl thionobenzenephosphonate (EPN).—This compound was used as a 27 per cent wettable powder. On Delicious apple trees in a preventive schedule of two applications, it was employed at a dosage of 3.2 ounces. This schedule provided control of the two-spotted spider mite that was equivalent to the parathion standard, although inferior to other treatments. EPN provided control of the European red mite for at least 5 weeks, being superior to parathion for this species (Table 2). The effectiveness of this compound for European red mite has also been reported by Chapman & Lienk (1950). Over a 21-day period, EPN provided corrective control of the clover mite which was superior to parathion (Table 3). In preventive programs observed over a 90-day period, however, EPN was distinctly less effective than parathion or dicyclohexylamine dinitro-*o*-cyclohexylphenate for control of clover mite (Table 4). For control of two-spotted spider mite on Bartlett pear trees, results (Table 8) show the inadequacy of a 3.2-ounce dosage of EPN in corrective sprays designed for 30-day protection. A 4.3-ounce dosage offered more promise in this respect. In a preventive program, with a 45-day spacing between applications (Table 9), a 4.3-ounce dosage of EPN did not provide satisfactory control. Surface residues of EPN on unwashed fruit (apples and pears) at harvest, analyzed by the parathion method, were less than 0.4 p.p.m. (Tables 2, 8, 9).

Octamethyl pyrophosphoramide (OMPA).—OMPA was used as an unformulated technical grade chemical containing 72 to 78 per cent of this compound. When applied in a preventive schedule of two applications of a 9-ounce dosage, it provided very good seasonal control of both two-spotted spider mite and European red mite on Delicious apples (Table 2). After the second application, slight marginal necrosis was noted on 10 per cent of the leaves. In addition to the replicated plots, one half of each of three mature Delicious apple trees was sprayed with OMPA according to the schedule described in table 2. The unsprayed halves of these trees became very heavily infested with both two-spotted spider mite and European red mite. The sprayed portions, though subjected to intense reinfestation, remained free of damaging mite infestations for a period of 5 weeks after application.

0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate (Compound 3901).—This compound, which was employed as a 25 per cent wettable powder, was given seasonal trial in a two-spray preventive schedule, using dosages of 2 and 3 ounces for control of two-spotted spider mite and European red mite on Delicious apple trees (Table 2). Two sprays applied at 4-week intervals provided control which was distinctly superior to that provided by parathion at the same dosage.

S-carbamylmethyl-0,0-dimethyl dithiophosphate (Compound 3869).—In a program similar to that described above, this compound, which was also employed as

a 25 per cent wettable powder, was intermediate in effectiveness between Compound 3901 and parathion (Table 2). Similar results with compounds 3901 and 3869 are recorded by Dean (1950) and by Chapman & Lienk (1950).

S-(1,2-dicarbethoxyethyl)-0,0-dimethyldithiophosphate (Compound 4049).—As employed in trials on apples (Table 2) and on pears (Table 9), this compound, used as a 16 per cent wettable powder, showed promising acaricidal value for two-spotted spider mite and European red mite. For control of these species equivalent to that provided by other compounds, an increase in dosage above the highest level employed in these trials (2.6 ounces), or a reduction in the interval between applications (48 and 35 days) is indicated.

S-(1,2-dicarbethoxyethyl-0,0-diethyl dithiophosphate (Compound 3975) and S-(1,2-dicarbomethoxyethyl)-0,0-diethyl dithiophosphate (Compound 4018).—Both of these compounds, when used as emulsifiable solutions containing 48 per cent and 47.7 per cent, respectively, and applied as described in table 2, provided adequate control of European red mite. A dosage greater than 4 ounces would be indicated in attempting to improve the control of two-spotted spider mite provided by these compounds.

0-(2-chloro-4-nitrophenyl)-0,0-dimethyldithiophosphate (Compound 4124).—When used as an emulsifiable solution containing 25 per cent, and at a 4-ounce dosage, this compound was of little acaricidal value (Table 2).

2-(p-tert-butylphenoxy) isopropyl 2-chloroethyl sulfite (Compound 88R).—This compound was used as a 15 per cent wettable powder. In preventive schedules for seasonal control of severe infestations of two-spotted spider mite and European red mite on Delicious apple trees, it was initially tried at two dosages (1.8 and 3 ounces) in two applications, with an interval of 30 days between sprays. As shown in table 2, the 1.8-ounce dosage was highly effective for control of European red mite but was not sufficient for control of two-spotted spider mite. The 3-ounce dosage provided excellent control of both species. Data in table 2 show that two applications of 3.6 ounces at an interval of seven weeks provided excellent control of both these species in severe infestations. Data from trials with this compound for clover mite control on Delicious apple trees are shown in tables 3 and 4. A dosage as high as 4 ounces may be required for adequate corrective applications for this species. A dosage of 3.1 ounces was sufficient for fair preventive control for 90 days, when applied at the pink stage, as described in table 4.

For control of Pacific mite on Bartlett pear trees, 2-(*p-tert*-butyl-phenoxy) isopropyl 2-chloroethyl sulfite was tried at a 3.6-ounce dosage in comparison with other materials in the one-spray preventive program described in table 6. Under the conditions of this trial, the described application provided very good commercial control for the season, a period of 80 days. An adjacent block of trees received a 3-ounce dosage of parathion in a single application and was 35 to 40 per cent defoliated by mites. Data in table 8 show that this compound was successfully employed at a dosage of 4.8 ounces in two applications with a 34-day interval between sprays, for adequate corrective control of a severe infestation of two-spotted spider mite. In a preventive program, a 2.4-ounce dosage in two applications with a 35-day interval between provided fair control in the trial described in table 9. In a preventive program, a dosage of 3.6 ounces is indicated for future trial. As a result of applications of this compound, a slight russeting of Bartlett pears has been noted at the drip point of the fruit. Surface residues on unwashed apples and pears, analyzed by the ethylene oxide method, were less than 0.5 p.p.m. at harvest (Tables 2, 8, 9).

p-Chlorophenyl-p-chlorobenzenesulfonate (Compound K-6451).—This compound was used as a 50 per cent wettable powder. For seasonal control of two-spotted spider mite and European red mite in a preventive schedule on Delicious apple trees, it was employed in the initial trial at two dosages, 4 ounces and 8 ounces, in two applications with a 30-day interval. The 8-ounce schedule provided very good control of two-spotted spider mite, as shown in table 2. This compound is unusually effective against the eggs of this species. It provided low initial mortality of adults, as indicated by counts made 24 hours after the second application in this trial and not recorded in the table.

Satisfactory control of European red mite was also achieved. The trend in

results with the latter species (Table 2) was not consistent with the dosage. This may be attributed to sampling error. In a subsequent trial on Delicious apple trees (Table 2), the initial application of 16 ounces may have been sufficient for seasonal control of two-spotted spider mite. It was necessary to re-treat after 7 weeks for control of the coexisting infestation of European red mite. Spray injury involving 40 per cent of the fruits and characterized by the development of blackened areas in the stem pit has resulted from applications of this compound on Delicious apples. As a corrective spray for clover mite control on Delicious apples (Table 3), promising results were obtained with a 1-pound dosage. Data in table 4 show excellent 90-day control of this species when an 8-ounce dosage was used in a preventive application.

Data presented in table 6 show the inadequacy of a single application of an 8-ounce dosage of *p*-chlorophenyl-*p*-chlorobenzenesulfonate for seasonal control of Pacific mite on Bartlett pear trees. In the corrective trials for two-spotted spider mite on Bartlett pears (Table 8), the initial application of a 16-ounce dosage provided adequate control for a period of 34 days, at which time re-treatment was required. In preventive trials (Table 9), an 8-ounce dosage provided excellent seasonal control of two-spotted spider mite when applied twice, with a 35-day interval between applications.

2,4-Dichlorophenylbenzenesulfonate (Compound 923).—This compound was used as a 25 per cent wettable powder and as a 50 per cent emulsifiable solution. As shown in table 2, when this compound was applied in two sprays at a dosage of 6 ounces, using the wettable powder, it failed to control two-spotted spider mite on Delicious apples. Counts made 4 weeks after the first application indicated a 97 per cent reduction of European red mite by the 6-ounce dosage, as compared with check-tree populations. When employed at 8 ounces (Tables 3 and 4), it provided very good control of clover mite. This compound gave promising results against the Pacific mite on Bartlett pears (Table 6). An increase in dosage over the 6 ounces employed is indicated for possible extension in length of protection. When applied in a preventive two-spray schedule of a 12-ounce dosage, using either the wettable powder or the emulsifiable solution with 35 days between applications, 2,4-dichlorophenylbenzenesulfonate did not provide adequate control of the two-spotted spider mite on Bartlett pears, under the circumstances of the trial reported in table 9.

p-Chlorophenyl phenylsulfone (Compound R-242).—This compound was used as a 50 per cent wettable powder. The initial trial (Barnes 1949) showed acaricidal value in a light infestation of Pacific mite and clover mite on Delicious apple trees. On Delicious apple trees in 1950, very good control of both two-spotted spider mite and European red mite resulted from a preventive program of two sprays of a 1.5-pound dosage, with a 48-day interval between applications (Table 2). The ovicidal value of this compound for summer eggs of the European red mite has been reported by Eaton & Davies (1950). The 1.5-pound dosage provided control of the clover mite for at least 90 days in the preventive trial described in table 4. On Bartlett pear trees, two sprays of a 1-pound dosage provided fair preventive control of two-spotted spider mite when applied with a 35-day interval between applications (Table 9). A 1.5-pound dosage is indicated for future trials.

1,1-Bis-(p-chlorophenyl)-methylcarbinol (DMC).—This compound was available as a 25 per cent emulsifiable formulation. It was also formulated as a wettable powder of 25 per cent strength by impregnating a clay diluent[6] with an acetone solution of the technical grade chemical, adding 0.25 per cent of a wetting agent[7] and grinding the mixture once through a micropulverizer, using a 0.035 herringbone screen. As an emulsifiable solution, this compound afforded excellent control of the two-spotted spider mite and European red mite when it was applied at a 4-ounce dosage in two-spray preventive schedules on Delicious apples (Tables 1 and 2). The wettable powder provided control equivalent to that attained by the emulsifiable solution (Table 2). When a single application was employed at a 6-ounce dosage derived from the emulsifiable solution, control of these species extended over a period of approximately eight weeks (Table 2). Clover mite control was ex-

[6] *Attaclay*; Attapulgus Clay Company.

[7] *Triton X-120*, containing *Triton X-100*, a polyethylene glycol monoiso-octyl phenyl ether impregnated on a suitable carrier; supplied by Rohm & Haas Company.

cellent following a preventive schedule of two 4-ounce sprays derived from the emulsifiable solution (Table 1). Hough (1948) and Newcomer & Dean (1949) reported results which indicate that under their conditions DMC was less effective for European red mite than in these trials. The acaricidal properties of this and related compounds have been described by Grummitt (1950).

Bis-(p-chlorophenoxy)-methane (Compound K-1875).—This compound was employed as a 40 per cent wettable powder. Jeppson (1946) has reported the effectiveness of this compound for control of the citrus red mite, *Paratetranychus citri* (McG). When used on Delicious apple trees in preventive sprays at the rate of 0.5 to 1 pound (Table 1), this compound afforded very good commercial control of the European red mite. Similar results were reported by Hough (1948). At the 1-pound dosage, control of the two-spotted spider mite was also achieved. At harvest, russeting was noted on 70 per cent of the fruit sprayed with the lower dosage and on all fruit sprayed with the higher dosage. This compound has little acaricidal value for the clover mite when employed at a dosage as high as 1 pound (Table 1). Similar results are reported by Newton & List (1949). A dosage of 8 ounces of bis-(*p*-chlorophenoxy)-methane did not provide satisfactory commercial control of Pacific mite on Bartlett pears, when used as described in table 5. The addition of 5 ounces of a spray adjuvant[8] apparently improved the control resulting from the 8-ounce dosage. It is noted that Newcomer & Dean (1948) achieved excellent results with this acaricide using a 13-ounce dosage in five applications for control of Pacific mite on apples.

1,1-Bis-(x-chlorophenyl)-ethane (K-3926).—This mixture of compounds was used as a liquid concentrate containing 2, 4, or 20 per cent of emulsifying agents. When used as described in table 1, on Delicious apple trees, it was distinctly more effective in controlling two-spotted spider mite than in controlling European red mite. Hough (1948) also reports that this material was not satisfactory for European red mite control. Its effectiveness for clover mite control was intermediate between that for other species (Table 1). On the basis of the results presented in tables 1 and 5, it may be stated that this mixture is unusually effective in preventive schedules for control of two species of *Tetranychus*. Metcalf (1948) reported acaricidal value for 1,1-bis-(*p*-chlorophenyl)-ethane in laboratory studies with the citrus red mite. It follows that this compound may be the active ingredient of the mixture employed in the present trials.

Alkyl-2-thiazolinyl sulfide (IN-4200).—This mixture of lauryl and other long-chain alkyl-2-thiazolinyl sulfides was used as an emulsifiable preparation containing 75 per cent of active ingredients. In a two-spray program on Delicious apples (Table 1), a 0.375-pint dosage was more effective against two-spotted spider mite and European red mite than against clover mite. A dosage of 0.75 pint followed by one of 1.5 pints afforded very good preventive control of all three species. Hough (1948) recorded promising short-term control of European red mite with this material. Newcomer & Dean (1949) reported that control of European red mite by this material was superior to that provided by parathion. As a corrective spray for clover mite (Table 3) at a dosage of 0.75 pint, re-treatment was required after 5 weeks. When applied to Bartlett pear trees in four formulations which varied in the process used to remove lauryl chloride from the technical product prior to formulation, this mixture caused injury to the epidermal cells of the fruits, chiefly at the drip point.

Dicyclohexylamine dinitro-o-cyclohexylphenate.—Used as a 20 per cent wettable powder in a two-spray preventive schedule of 2.4 ounces (Table 1), this compound afforded an 85 per cent reduction of two-spotted spider mite on Delicious apple trees. This dosage failed to control European red mite. This compound is unusually effective for control of clover mite (Tables 1, 3, and 4).

For Pacific mite on Bartlett pear trees, dicyclohexylamine dinitro-*o*-cyclohexylphenate usually affords fair control when two applications are made at a 2.4-ounce dosage (Table 5). In some seasons, however, this dosage fails to provide satisfactory control (Table 7). Higher dosages may not be used because of the hazard of injury to the fruit, and during some

[8] *Colloidal Z-1*; principal active ingredients, petroleum sulfonates and combined fatty acids; supplied by Colloidal Products Corporation.

Table 7.—Effect of variation in sequence and volume of applications in treatment schedules for control of the Pacific mite on Bartlett pear trees, Antelope Valley, California, 1949.[1]

Schedule No., Material and Formulation[2]	Gallons per Acre	Date of Application and Active Ingredient per 100 Gal.				Average Rating[3] of Mite Injury (Defoliation)	
		May 1	June 17	July 13	Aug. 6	July 13	Aug. 17
1. DDT 50-W	1,000	1 lb.	1 lb.	—	—	1.3	1.3
Parathion 25-W	1,000	—	—	3 oz.	3 oz.		
2. DDT 50-W	500	2 lb.	2 lb.	—	—	1.2	2.9
Parathion 25-W	500	—	—	6 oz.	6 oz.		
3. DDT 50-W	1,000	1 lb.	—	1 lb.	—	0.2	5.0
Parathion 25-W	1,000	—	3 oz.	—	3 oz.		
4. DDT 50-W	500	2 lb.	—	2 lb.	—	0.2	4.9
Parathion 25-W	500	—	6 oz.	—	6 oz.		
5. DDT 50-W	1,000	1 lb.	1 lb.	—	—	1.2	4.0
Dicyclohexylamine dinitro-*o*-cyclohexylphenate 20-W	1,000	—	—	2.4 oz.	2.4 oz.		

[1] Sprays applied with a semiautomatic sprayer equipped with rotating guns on a vertical boom supplied by an 80 g.p.m. pump, to unreplicated plots 35 yards wide.
[2] In percentage of wettable powder (W).
[3] Average of defoliation ratings noted on 10 trees by two observers: 0 = none, 1 = light, 2 = light-medium, 3 = heavy-medium, 4 = severe, 5 = very severe.

seasons this may be a factor even at the 2.4-ounce dosage level.

Discussion.—In orchard practice, preventive sprays are generally more satisfactory than corrective applications for mite control. This is partly because of the greater number of mites surviving corrective treatment, although the percentage mortality may in some cases be the same as for preventive sprays. Mite species that web profusely are of course more difficult to contact when their infestations are well established. In addition, the higher temperatures prevailing as the season advances may, as with parathion, increase the rate of attenuation of spray deposits and reduce the percentage control of the established infestations which are then encountered. The developmental stage for which a material is toxic may also affect its usefulness as a preventive or corrective spray. According to Sherman & King (1948), bis-(*p*-chlorophenoxy)-methane was effective when used preventively for two-spotted spider mite, but was notably ineffective in corrective sprays because of low toxicity to hatched forms. This was also true for *p*-chlorophenyl-*p*-chlorobenzenesulfonate in the present studies.

Melvin (1948) has shown that soil and a variety of other substances on bean foliage markedly reduce the acaricidal properties of tetraethylpyrophosphate dips, with similar trends for parathion. In most of the fruit-growing areas of southern California there is no rainfall during the summer, and the gradual accumulation of dust deposits on the foliage as the season progresses may contribute to lower the effectiveness of corrective applications, as compared with preventive applications.

The use of herbicidal sprays, as mentioned above, to eliminate the cover crop as a source of reinfestation by two-spotted spider mite undoubtedly extends the protection afforded by the acaricidal sprays reported in tables 1 and 2. Several of the candidate acaricides employed were characterized, however, by the extended periods over which they provided protection, although the trees treated were subjected to intense reinfestation by this species (Tables 8 and 9). Included in this group were the following: *p*-chlorophenyl *p*-chlorobenzenesulfonate, 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite, *p*-chlorophenyl phenylsulfone, and octamethylpyrophosphoramide. Foliage sprayed with the last-named compound was also subjected to reinfestation by the European red mite, since half-tree plots were used.

The specificity of action which many acaricides possess for certain species of mites is well substantiated by numerous examples reported.

Summary.—1. When applied in preventive schedules for control of mites on Delicious apple trees in southern California, some of the more promising new acaricides may be rated approximately as follows, on the basis of current information and in consideration of the

Table 8.—Effect of corrective applications of various acaricides for control of the two-spotted spider mite on Bartlett pear trees, Antelope Valley, California, 1950.[1]

TREATMENT NO., MATERIAL[2] AND FORMULATION[3]	SCHEDULE OF APPLICATIONS AND ACTIVE INGREDIENT PER 100 GAL.			AVERAGE RATING[4] OF MITE INJURY (DEFOLIATION) JULY 25
	June 21	July 20	July 25	
	Ounces	*Ounces*	*Ounces*	
1. Parathion 25-W	4	4	—	2.6
2. Ethyl-*p*-nitrophenyl thionobenzenephosphonate 27-W	3.2	4.3[5]	—	2.4
3. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	3.6	4.8[5]	—	2.5
4. 2-(*p-tert*-butylphenoxy) islpropyl 2-chloroethyl sulfite 15-W	4.8	—	4.8	1.8
5. *p*-Chlorophenyl-*p*-chlorobenzenesulfonate 50-W	16	—	16	1.1

[1] Plots 1.5 acre each, 40 yards wide, replicated twice. Sprays applied with semiautomatic sprayer equipped with rotating guns on a vertical boom supplied by an 80 g.p.m. pump, this application affording fair spray coverage of a heavily infested natural cover of wild morning-glory.

[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal. water. Analyses of duplicate samples of 20 fruits each (4 fruits from each of 5 trees) at harvest, August 7, showed surface residues of 0.06 p.p.m. EPN from treatment, 2, and residues of 0.43 p.p.m. of compound 88R from each of treatments 3 and 4.

[3] In percentage wettable powder (W).

[4] Average of defoliation ratings noted by one observer on 10 trees in each plot; 0 = none, 1 = light, 2 = light-medium, 3 = heavy-medium, 4 = severe, 5 = very severe. The second application effectively held mites under control in all plots through harvest, August 18–20. Observations were terminated by conventional post-harvest spray of 2 per cent light-medium oil.

[5] Dosage increased because initial dosage employed did not effectively hold infestation under control for the indicated interval.

Table 9.—Effect of two preventive applications of various acaricides for control of the two-spotted spider mite on Bartlett pear trees, Antelope Valley, California, 1950.[1]

TREATMENT NO., MATERIAL[2] AND FORMULATION[3]	ACTIVE INGREDIENT PER 100 GAL.	SCHEDULE OF APPLICATIONS	AVERAGE RATING[4] OF MITE INJURY (DEFOLIATION) JULY 19 AND SEPT. 12
	Ounces		
1. Parathion 25-W	3	6/15, 7/20	3.5
2. S-(1,2-dicarbethoxyethyl)-0,0-dimethyl-dithio-phosphate 16-W	1.3	6/15, 7/20	2.7
3. Ethyl-*p*-nitrophenyl thionobenzenephosphonate 27-W	2.2	6/15, 7/20	2.1
4. Ethyl-*p*-nitrophenyl thionobenzenephosphonate 27-W	4.3	6/15, 7/31	1.9
5. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	2.4	6/15, 7/20	1.6
6. 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite 15-W	4.8	6/15, 7/31	1.1
7. *p*-Chlorophenyl-*p*-chlorobenzenesulfonate 50-W	8	6/15, 7/20	0.9
8. *p*-Chlorophenyl-*p*-chlorobenzenesulfonate 50-W	16	6/15, 7/31	0.7
9. 2,4-Dichlorophenylbenzenesulfonate 25-W	12	6/15, 7/20	3.3
10. 2,4-Dichlorophenylbenzenesulfonate 50-E	12	6/15, 7/20	2.6
11. 2,4-Dichlorophenylbenzenesulfonate 50-E	12	6/15, 7/31	2.7
12. *p*-Chlorophenyl phenylsulfone 50-W	16	6/15, 7/20	1.4
13. *p*-Chlorophenyl phenylsulfone 50-W	32	6/15, 7/31	1.0

[1] Sprays applied to single-tree plots replicated in 15 blocks, using conventional equipment and ground leads. No effort was made to spray the heavily infested cover crop of alfalfa.

[2] All materials were in addition to 1 lb. 50 per cent DDT wettable powder per 100 gal. water. Analyses of duplicate samples of 20 fruits each (4 fruits from each of 5 trees) at harvest, August 7, showed surface residues of 0.06 and 0.36 p.p.m. EPN from treatments 3 and 4, respectively, and residues of 0.09 and 0.18 p.p.m. compound 88R from treatments 5 and 6, respectively.

[3] In percentage wettable powder (W) or emulsifiable solution (E).

[4] Average of defoliation ratings noted by one observer on 15 replicates: 0 = none, 1 = light, 2 = light-medium, 3 = heavy medium, 4 = severe, 5 = very severe.

several factors involved: (a) For control of the two-spotted spider mite in the absence of reinfestation from the orchard cover, 1,1-bis-(*p*-chlorophenyl)-methylcarbinol = 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite = octamethyl pyrophosphoramide > *p*-chlorophenyl-*p*-chlorobenzenesulfonate > *p*-chlorophenyl phenylsulfone > ethyl-*p*-nitrophenyl thionobenzenephosphonate = parathion > dicyclohexylamine dinitro-*o*-cyclohexylphenate > 2,4-dichlorophenylbenzenesulfonate. (b) For control of the European red mite, 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite = 1,1-bis-(*p*-chlorophenyl)-methylcarbinol = ethyl-*p*-nitrophenyl thionobenzenephosphonate = octamethyl pyrophosphoramide = 2,4-dichlorophenyl-benzenesulfonate = *p*-chlorophenyl phenylsulfone > *p*-chlorophenyl-*p*-chlorobenzenesulfonate = parathion > dicyclohexylamine dinitro-*o*-cyclohexylphenate. (c) For control of clover mite, dicyclohexylamine dinitro-*o*-cyclohexylphenate = parathion = 1,1-bis-(*p*-chlorophenyl)-methylcarbinol > *p*-chlorophenyl-*p*-chloro-benzenesulfonate = 2,4-dichlorophenylbenzenesulfonate > 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite = *p*-chlorophenyl phenylsulfone > ethyl-*p*-nitrophenyl thionobenzenephosphonate.

2. When applied in preventive schedules for two-spotted spider mite on Bartlett pear trees subjected to reinfestation from the orchard cover, *p*-chlorophenyl *p*-chlorobenzenesulfonate = 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite > *p*-chlorophenyl phenylsulfone > ethyl-*p*-nitrophenyl thionobenzenephosphonate > 2,4-dichlorophenylbenzenesulfonate > parathion.

3. Other compounds sufficiently effective as acaricides to warrant further study include 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate; S-carbamylmethyl-0,0-dimethyl dithiophosphate; S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate; S-(1,2-dicarbethoxy)-0,0-diethyl dithiophosphate; and S-(1,2-dicarbomethoxyethyl)-0,0-diethyl dithiophosphate.

4. Compounds of a lower order of effectiveness as acaricides include 1,1-bis-(x-chlorophenyl)-ethane and 0-(2-chloro-4-nitrophenyl)-0,0-dimethyl dithiophosphate.

5. Acaricides causing fruit injury sufficiently severe to preclude use unless corrected, if possible, by improvement in formulation or by use of reduced dosages were the following. On Delicious apples, bis-(*p*-chlorophenoxy)-methane caused russeting and *p*-chlorophenyl-*p*-chlorobenzenesulfonate caused blackening of the epidermis in the stem pit area. On Bartlett pears, alkyl-2-thiazolinyl sulfide caused fruit spotting. A slight russeting of Bartlett pears resulted from applications of 2-(*p-tert*-butylphenoxy) isopropyl 2-chloroethyl sulfite.

LITERATURE CITED

Barnes, M. M. 1949. Investigations on the control of insects and mites on apple, pear, and peach in southern California in 1949. Report to Western Cooperative Spray Project. 18 p. (Mimeo.)

Barnes, M. M., G. E. Carman, W. H. Ewart, and F. A. Gunther. 1950. Fruit surface residues of DDT and parathion at harvest. Advn. in Chem. Ser. **1**: 112–6.

Chapman, P. J., and S. E. Lienk. 1950. Orchard mite control experiments in western New York. JOUR. ECON. ENT. **43**(3): 309–14.

Dean, R. W. 1950. Summer control of orchard mites in eastern New York. JOUR. ECON. ENT. **43**(2): 167–71.

Eaton, J. K., and R. G. Davies. 1950. The toxicity of certain synthetic organic compounds to the fruit-tree red-spider mite. Ann. Appl. Biol. **37**: 471–89.

Grummitt, Oliver. 1950. Di-(*p*-chlorophenyl)methylcarbinol, a new miticide. Science **111**: 361–2.

Hough, W. S. 1948. Control of mites on apple trees sprayed with DDT. JOUR. ECON. ENT. **41**: 207–9.

Jeppson, L. R. 1946. Di(4,chlorophenoxy)methane for control of citrus red mite. JOUR. ECON. ENT. **39**: 813.

Melvin, Roy. 1948. Effect of dusts on the performance of tetraethyl pyrophosphate. JOUR. ECON. ENT. **41**: 903–4.

Metcalf, R. L. 1948. Acaricidal properties of organic compounds related to DDT. JOUR. ECON. ENT. **41**: 875–82.

Newcomer, E. J., and F. P. Dean. 1946. Effect of xanthone, DDT, and other insecticides on the Pacific mite. JOUR. ECON. ENT. **39**: 783–6.

Newcomer, E. J., and F. P. Dean. 1948. Studies of orchard acaricides. JOUR. ECON. ENT. **41**: 691–4.

Newcomer, E. J., and F. P. Dean. 1949. Comparative effectiveness of orchard acaricides. JOUR. ECON. ENT. **42**: 857–8.

Newton, J. H., and G. M. List. 1949. Codling moth and mite control in 1948. JOUR. ECON. ENT. **42**: 346–8.

Sherman, Franklin, III, and H. L. King. 1948. Tests in 1947 against the two-spotted spider mite. JOUR. ECON. ENT. **41**: 807–8.

Control of Peach Tree Borer and Lesser Peach Tree Borer in New York[1]

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Peach trees in New York State are subject to attack by two species of borers, the peach tree borer, *Sanninoidea exitiosa* (Say) and the lesser peach tree borer, *Synanthedon pictipes* (G. & R.). Control of the peach tree borer has been the object of extensive investigations, but much less consideration has been given to control of the lesser species. The standard program for control of the peach tree borer has consisted of three spray applications of DDT used at the rate of 3 pounds (50 per cent W. P.) per 100 gallons of water. These sprays are applied at 21-day intervals beginning approximately July 15. No practical spray program for control of the lesser peach tree borer has been available to growers.

While the peach tree borer control program has been reasonably effective, it has two chief disadvantages. First, the final spray comes too near harvest. At this time, tree trunks are difficult to spray because of the dense foliage, and fruit frequently may be dislodged in maneuvering spray machinery through the rows. The second disadvantage is that this program has proved ineffective against the lesser peach tree borer. The consequence of this situation was that growers, confusing the two species, often erroneously concluded that the program was ineffective against all borers. The need of a program effective against both species became apparent. Efforts to develop such a program were begun in 1949. The present report covers investigations conducted during 1949 and 1950.

Biology and Habits.—The chief differences in the biology and habits of the two species which might influence control measures are: area of the tree infested, length of life cycle and period of moth emergence.

The peach tree borer confines its activities largely to the trunk below soil level. The presence of wounds in the bark surface is not necessary for the establishment of this species. By contrast, the lesser peach tree borer may be found on any portion of the tree and generally enters at points of the bark surface where injury occurs. Although lesser peach tree borers are generally most prevalent on the trunk above soil level and in branches, substantial numbers occur on the trunk below soil level in trees having trunk wounds which extend to the soil level. Such wounds, resulting from winter injury, are rather common in this locality.

The majority of the peach tree borers have a 1-year life cycle, but approximately 30 per cent require two years to complete development. The borers which are in their second year of development can be distinguished in the fall by their larger size. These borers appear full grown at that time and are in the final or sixth instar. The borers arising during the current season are smaller in size being represented by instars 5, 4 and 3. The presence of borers having a 2-year life cycle is of practical significance for several reasons. First, control measures are less effective against these borers because of their inaccessability and large size at the time of treatment. Also, excessive injury is caused by these larvae during their second year of feeding. The lesser peach tree borer completes its development in one year. A considerable portion of the larval population reaches the sixth or final instar by fall.

The period of moth emergence of the two species is perhaps the most significant difference relating to control measures. The peach tree borer moths emerge during July and August while emergence of the lesser peach tree borer moths extends from late May until early fall.

Experimental Method.—At best, the taking of data in peach tree borer control experiments is difficult because of the physical limitations imposed. The borers must be removed individually. This is a time-consuming and laborious operation which limits the number of trees that can be examined. Furthermore, conclusions must be drawn on the basis of relatively small numbers of individuals. In the present study, all borers were collected in October and segregated on the basis of their location on the tree. The specimens were preserved and stored for later

[1] New York Agricultural Experiment Station Journal Paper No. 860, April 25, 1951.

study to determine species and instar, since these points cannot be determined with certainty in the field. Instars were determined on the basis of head capsule measurements and morphological characteristics. These points will be covered in detail in a later report.

1949 CONTROL EXPERIMENTS.—The objective of the 1949 tests was to determine the effectiveness of peach tree borer sprays against both species of borers. Parathion and DDT were used at several concentrations. Plots were located in a 15-year old Elberta peach orchard at Morton, New York, in which moderately severe infestations of both species occurred. All treatments were applied with a standard hydraulic orchard sprayer operating at 400 pounds pump pressure. The operator of the spray gun was seated on a low platform at the rear of the spray rig. From this position, the trunk and scaffold branches could be readily sprayed from opposite sides of the row as the rig moved continuously at a slow rate of speed. No attempt was made to cover the foliage of the trees. Sprays were applied on July 13, August 4 and August 30. Each plot consisted of a 20-tree row, and plots were replicated twice. In taking results, all borers were collected from 10 or more trees in each treatment. The data pertaining to peach tree borer larvae are given in table 1. It will be noted that 32 borers or 34 per cent of the individuals taken from untreated trees were in the sixth instar. As pointed out earlier, these borers were in their second year of larval feeding. All treatments with the exception of DDT at the rate of 2 pounds per 100 gallons controlled the borers of the current season. It was apparent that DDT at the rate of 6 pounds per 100 gallons was not highly effective against sixth instar larvae. The high survival of sixth instar larvae in this treatment appeared to be inconsistent with results obtained with 4 pounds of DDT. However, considering the wide variation in infestation between individual trees and the small number of trees examined, this difference is understandable. In this case, a single tree in a plot treated with 6 pounds of DDT yielded eight, sixth instar, borers. Parathion at 2 and 4 pounds per 100 gallons was more effective than DDT at comparable dosages.

The data pertaining to lesser peach tree borers collected on the trunk below soil level are shown in table 2. It is of interest to note that five lesser peach tree borers per tree were found on the trunk below soil level on untreated trees. Thus, 37 per cent of the borers taken below soil level were of the lesser species. In comparing the effectiveness of various materials against the two species (Tables 1 & 2), it appeared that all treatments were slightly less effective against the lesser peach tree borer than against the peach tree borer.

The individuals collected from the trunk above soil level and from the branches were all lesser peach tree borers with the exception of three individuals taken from the trunks of untreated trees. The data on the lesser peach tree borers collected from trunks and branches are given in tables 3 and 4. It is apparent that control of larvae located on trunk and branches was not as good as control of larvae of the same species which occurred below soil level. The instars of the surviving larvae are of particular interest. In all DDT treatments some of the smallest larvae survived, whereas, in the parathion treatments, the survivors were all of the larger instars.

The conclusions drawn from these data are: (1) parathion was more effective than

Table 1.—Peach tree borer control experiments at Morton, N. Y. 1949.

MATERIAL	AMT. PER 100 GALS.	NO. TREES EXAMINED	AVERAGE BORERS PER TREE	TOTAL BORERS COLLECTED	INSTARS REPRESENTED			
					6	5	4	3
DDT (50% WP)	2 lbs.	17	0.7	12	10	0	2	0
	4	13	0.1	2	2	0	0	0
	6	14	1.0	14	14	0	0	0
Parathion (15% WP)	2	15	0.3	5	5	0	0	0
	4	13	0.0	0	0	0	0	0
Untreated		11	8.4	93	32	38	19	4

Sprays applied: July 13, August 4, August 30.

Table 2.—Control of lesser peach tree borers occurring on trunks below soil level. Morton, N. Y. 1949.

Material	Amt Per 100 Gals.	No. Trees Examined	Average Borers Per Tree	Total Borers Collected	Instars Represented			
					6	5	4	3
DDT (50% WP)	2 lbs.	17	1.4	24	16	7	1	0
	4	13	0.4	5	5	0	0	0
	6	14	0.7	11	11	0	0	0
Parathion (15% WP)	2	15	0.2	4	4	0	0	0
	4	13	0.1	2	2	0	0	0
Untreated		11	5.0	55	27	15	10	3

Sprays applied: July 13, August 4, August 30.

DDT in control of the peach tree borer, and (2) parathion sprays timed for control of the peach tree borer gave substantial reduction in the lesser peach tree borer infestations.

1950 CONTROL EXPERIMENTS.—In view of the indication obtained in 1949 that parathion was promising for control of the lesser peach tree borer, further studies with this material were continued during 1950. A single concentration of spray, 2 pounds (15 per cent W. P.) per 100 gallons, was used in all treatments. For these tests a heavily infested, 18-year-old Elberta peach orchard at Geneva, New York was selected. Sprays were applied in the same manner as described for the 1949 tests. Plots consisted of single 20-tree rows, and plots were replicated twice. Plots were so arranged that the effectiveness of a single spray or the combination of sprays could be evaluated. At the time of each spray application a collection of larvae was made to determine the stage of development of the larvae at this time. In taking control data, borers were collected from the trunks and branches of five trees in each row giving a total of ten trees per treatment. Larvae were not collected from the trunk below soil level because the infestation of peach tree borers in this orchard was light. The rate of moth emergence of the lesser peach tree borer was determined from weekly collections of empty pupal cases taken from 30 heavily infested untreated trees adjoining the sprayed plots. This method has proved satisfactory as the pupal cases are not readily dislodged and can be easily detected. More extensive observations can be made in this way than by actually trapping the moths through the use of cages. Similar records on moth emergence were obtained for the peach tree borer.

Three sprays were applied at 21-day intervals. The first one was applied on June 22 when 15 per cent of the moths had emerged. At the time of this application very few larvae of the current brood could be found. The largest of those collected were in the third instar.

At the time of the second application the oldest larvae had reached the fifth instar. Sixth instar larvae were present when the last spray was applied on August 3. The timing of sprays in relation to moth emergence is shown in figure 1.

The data pertaining to larvae collected from each plot during October are given in table 5. It will be seen that each of the

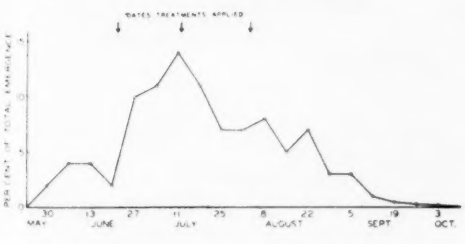

FIG. 1.—Showing the timing of sprays in relation to lesser peach tree borer moth emergence in 1950.

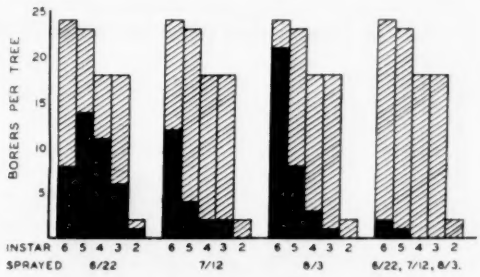

FIG. 2.—Showing effect of parathion sprays on lesser peach tree borer. Cross-hatched portion represents population in untreated trees. Solid portion represents survivors.

Table 3.—Control of lesser peach tree borers occurring on trunks. Morton, N. Y. 1949.

Material	Amt. Per 100 Gals.	No. Trees Examined	Average Borers Per Tree	Total Borers Collected	Instars Represented			
					6	5	4	3
DDT (50% WP)	2 lbs.	17	10.6	181	116	31	25	9
	4	13	5.8	76	59	8	8	1
	6	14	4.4	62	49	7	5	1
Parathion (15% WP)	2	15	1.3	20	20	0	0	0
	4	13	1.3	17	16	1	0	0
Untreated		11	14.9	164	61	26	46	31

Sprays applied: July 13, August 4, August 30.

individual sprays accounted for a reduction of over 50 per cent of the total larval infestation. The combination of three sprays reduced the borer population from an average of 85 borers per tree to 3 per tree, a reduction of 96 per cent.

The effect of these sprays in reducing the borer infestation is partially indicated by the stage of development of the individuals present when collections were made in October. As might be expected (Fig. 2) the most effective of the three sprays was the second which coincided with the peak of moth emergence (Fig. 1). A reduction of 76 per cent of the larvae occurred where this spray was applied alone. Of the 20 borers per tree which survived this treatment, 12 were full grown and were probably established prior to treatment. The remaining eight survivors were smaller and presumably became established at some time after treatment was made.

The third spray was next in effectiveness with 33 survivors per tree. The effectiveness of this spray was largely against the later developing larvae as indicated by the slight reduction in the number of sixth instar larvae present. While the first spray was least effective, it accounted for some reduction of larvae in each stage represented.

Although the first spray was applied when only 15 per cent of the moths had emerged, a 53-per cent reduction in larvae occurred. The last spray, applied when 72 per cent of the moths had emerged, gave a 61-per cent reduction. The results obtained from the first spray suggest that parathion possesses considerable residual action. That it also has eradicating value is indicated by results of the last application, for it seems likely that more established larvae were present at the time of this treatment than the 39 per cent which survived. The data cited in the foregoing indicate that considerable flexibility is permitted in the timing of sprays for control of the lesser peach tree borer. Obviously, this is a point of considerable practical significance.

In attempting to account for the control obtained from these treatments, the possible effect of sprays on moths has been considered. It seemed unlikely that the kill of moths accounted for appreciable

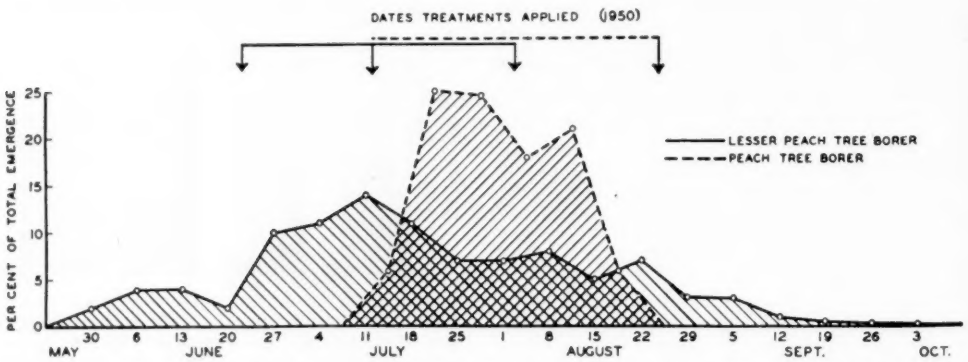

FIG. 3.—Showing the timing of sprays in relation to emergence of moths of the peach tree borer and the lesser peach tree borer during 1950.

Table 4.—Control of lesser peach tree borers occurring on branches. Morton, N. Y. 1949.

MATERIAL	AMT. PER 100 GALS.	NO. TREES EXAMINED	AVERAGE BORERS PER TREE	TOTAL BORERS COLLECTED	INSTARS REPRESENTED			
					6	5	4	3
DDT (50% WP)	2 lbs.	17	5.4	93	49	14	20	10
	4	13	2.0	27	18	2	5	2
	6	14	2.4	34	22	8	3	1
Parathion (15% WP)	2	15	1.2	18	17	1	0	0
	4	13	0.8	10	9	1	0	0
Untreated		11	6.0	67	23	12	20	12

Sprays applied: July 13, August 4, August 30.

control. Assuming that some moths were killed, an influx of moths from adjoining trees would be expected as plots were relatively small and were bordered by untreated rows. Furthermore, the treated plots were located on the west side of a 40-acre orchard in which the lesser peach tree borer was not effectively controlled.

DISCUSSION.—The 1950 tests did not permit the evaluation of these sprays against the peach tree borer. However, observations on the rate of moth emergence of both species were made, and this provided a basis for coordinating a program effective against both species. The timing required for control of the peach tree borer has been reasonably well established by observations extending over a number of years. According to these observations, the seasonal fluctuations in moth emergence are not sufficient to require appreciable changes in the timing of sprays from year to year. Observations on the emergence of lesser peach tree borer moths in this locality are limited to the record obtained in 1950. However, it seems likely that these data represent the general pattern of emergence. The timing of sprays for control of both species in relation to moth emergence during 1950

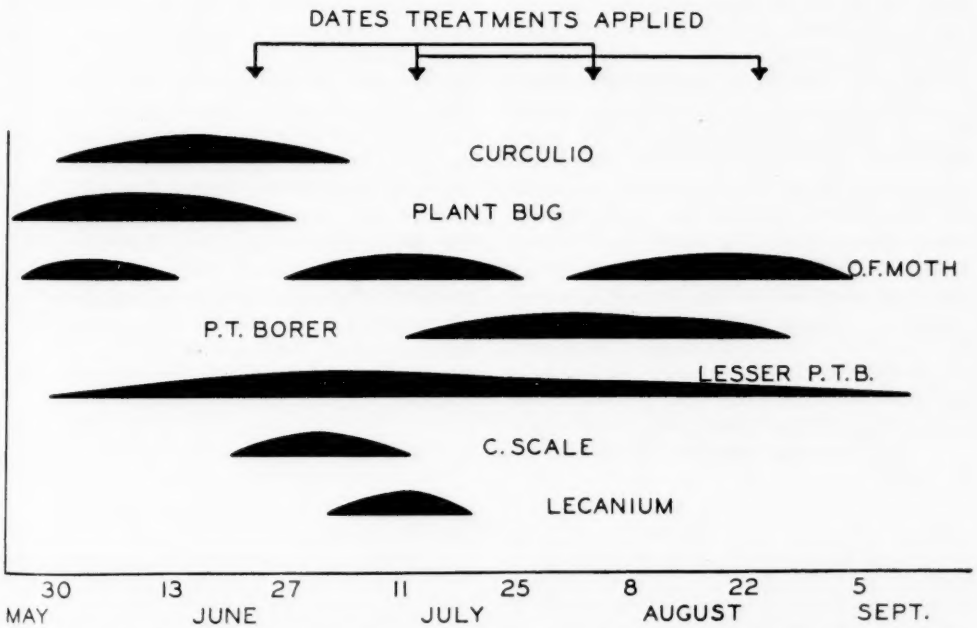

FIG. 4.—Showing the timing of borer sprays in relation to the seasonal development of other peach pests. 1950. (Curculio—plum curculio; plant bug—tarnished plant bug; O. F. moth—oriental fruit moth; P.T. borer—peach tree borer; lesser P.T.B.—lesser peach tree borer; C. scale—cottony peach scale; lecanium—European fruit lecanium.)

Table 5.—Control of lesser peach tree borers. Geneva, N. Y. 1950.

Date of Application	Ave. Number of Borers per Tree	Per Cent Reduction	Instars Represented				
			6	5	4	3	2
June 22	40	53	8	14	11	6	1
July 12	20	76	12	4	2	2	0
August 3	33	61	21	8	3	1	0
June 22, July 12, August 3	3	96	2	1	0	0	0
Untreated	85	—	24	23	18	18	2

is shown in figure 3. The timing shown for the peach tree borer was that recommended to growers for practical control. This timing coincided closely with the schedule of sprays used in the 1949 tests (Table 1). Of the four sprays indicated for control of the two species, the second and third would be expected to contribute most to joint control. The schedule set forth in figure 3 is tentatively proposed as a control program for the two species in this locality.

In view of the encouraging results obtained with parathion in control of borers, it seems desirable to consider the place of these sprays in the general pest control program. Parathion is currently being used in control of the major insect pests of peaches. In New York State these include, in addition to the two species of borers, the plum curculio, plant bugs, oriental fruit moth, cottony peach scale, European fruit lecanium and several species of mites. With the exception of the plum curculio and plant bugs, which are controlled earlier in the growing season, these other pests are susceptible to control during the period when borer sprays might be applied. The seasonal development of these pests during 1950, in relation to the timing of borer sprays, is shown in figure 4. Several of the borer sprays, particularly the second, might be adjusted to coincide with sprays for control of other pests. Any adjustment in timing must be made in the borer applications as the timing of other sprays permits less flexibility. The use of a parathion program for control of borers together with other peach pests has not been fully demonstrated, but it would appear to have wide practical application in this state.

Summary.—Field control studies using parathion and DDT were conducted during 1949 and 1950 against the peach tree borer and the lesser peach tree borer. Parathion proved more effective than DDT for control of the peach tree borer. The individuals of this species which survived treatments were largely those in their second year of development. The DDT program for control of the peach tree borer was relatively ineffective against the lesser peach tree borer. Parathion applied on the same schedule caused substantial reductions in the lesser peach tree borer infestation. Effective control of this species was obtained with three applications of parathion at the rate of 2 pounds (15 per cent W. P.) per 100 gallons. Sparys were applied at 21-day intervals beginning June 22. The last two of these sprays coincided with the first two sprays recommended for control of the peach tree borer. A program consisting of four spray applications of parathion is tentatively suggested for control of both species. The integration of these sprays into the general pest control program is considered.

A Correction

Dr. A. W. Lindquist has sent in the following correction: "We have noticed an error in the paper by Hoffman and Lindquist entitled "Studies on Treatment of Flies with Radioactive Phosphorus" on page 473, vol. 44(4) of the current Journal. I am sure that neither you, nor we, nor the printers was responsible for it. As far as we can determine our reviewers slipped this in without us recognizing it. The sentence just before the "Summary" reads ". . . large amounts (70,000 to 100,000 /uc)." The "/uc" is incorrect; this should be "cpm."

Could you make a correction and show that it is *cpm* and not microcurie in the next issue? The error is really fantastic because if this was 100,000 microcurie, we would not dare to get close to even one house fly because of the high activity."

Residue Studies on DDT and Parathion Applied to Lettuce for Control of the Six-spotted Leafhopper

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Lettuce yellows, a virus disease of lettuce, has been of economic importance in the lettuce producing areas of New York since it was first reported by Coons (1922). The extent of loss has varied to as high as 50 per cent of the total crop in 1946 and 1947, as reported by Ashdown & Watkins (1948). However, since 1947 the problem has been of somewhat less importance.

The virus causing the disease was first shown by Kunkel (1925) to be transmitted to lettuce by the six-spotted leafhopper, *Macrosteles divisus* Uhl. The only known method of combatting the disease is by controlling the insect vector. Experimental work has been carried on with several insecticidal materials but it was not until the advent of DDT that there was any degree of success in substantially reducing the incidence of lettuce yellows through the application of insecticides. Ashdown & Watkins (1948); Bowser (1946); Linn (1940); Pepper & Haenseler (1939); and Smith *et al.* (1945).

Because of the high incidence of the virus disease in 1946 and 1947 and the relative effectiveness of DDT in controlling the insect vector, various formulations of this material became widely used by the growers for the control of the leafhoppers. Although the economic importance of the disease since 1947 has lessened there is still a definite need for the lettuce growers in New York to apply regular scheduled applications of insecticides. The principal insecticide employed is some formulation of DDT but during the past 2 years parathion has been found to give comparable control and is used to a limited extent in the commercial production of lettuce.

The insecticide residue hazard has been apparent since DDT was first used on lettuce on a commercial scale. Ashdown and Watkins (1948) applied DDT dusts in various concentrations and found less than 1 ppm of DDT residue on the lettuce heads when the applications were ceased 2 to 3 weeks prior to harvest. They also found, when following this type of schedule, that most of the harvest residue was on the lettuce trimmings and only nominal amounts on the marketable heads. Robinson (1949a) reported that 5 per cent DDT dust applied to head lettuce when it was 4 inches in size produced a harvest residue of 0.07 ppm.

Several workers have reported the results of residue analyses at harvest time when DDT was applied to cabbage, which is similar to lettuce in its habit of growth. Carter (1948) determined the harvest residues when DDT had been applied to cabbage and found that the 4 wrapper leaves showed as high as 6 ppm DDT while the stripped heads had less than 0.5 ppm; even this small residue was attributed to the short interval between the last application and harvest. It was calculated from data reported by Manalo *et al.* (1946) that 21 days after an application of 5 per cent DDT dust the residue on the outermost mature leaves of cabbage was nearly 4 times as great as the residue on the small heads. Reiber & Stafford (1946) took cabbage samples for analyses 36 days after two applications of 3 per cent DDT dust and reported residues of 4.2 ppm DDT on the outer leaves and 1.1 ppm on the inner leaves.

A review of the literature revealed no information about parathion residues on lettuce or similar growing crops. Because of the lack of data pertaining to parathion residues, and the limited scope of the same type of information on DDT, particularly if the grower did continue applications beyond the recommended time for the last application, studies were started in 1949 to investigate this problem.

Experimental Procedure.—The DDT and parathion residue studies were made in Oswego County, New York, in conjunction with regular field experiments designed for six-spotted leafhopper control problems. The fields used were approximately 1 acre in size and each field was divided into 2 equal parts. One-half of each field was sprayed or dusted with a different insecticide or formulation and

compared with the other half as to effectiveness of control and the resulting reduction of the incidence of lettuce yellows. Check counts and untreated residue samples were obtained either from six to eight outside rows that were purposely left untreated in each treated plot or from neighboring untreated fields of lettuce. The results of the six-spotted leafhopper control experiments are not reported in this paper.

Normally, under commercial conditions, each field would receive four spray applications at weekly intervals or approximately 5 dust applications spaced 5 to 7 days apart. The applications started as soon as the lettuce rows were well marked with germinating plants and ceased some 2 to 3 weeks prior to harvest. For the purpose of the residue study it was desirable to bring the date of the last application closer to the date of harvest in some tests and to facilitate this, a number of the DDT and parathion spray plots received 5 to 6 applications.

The first 4 spray applications were made with a low pressure sprayer mounted on a garden type tractor.[1] In 1949 all sprays were applied using a 6-row boom with 1 nozzle per row. The wettable powder spray applications were made at the rate of 55 gallons per acre and at 60 pounds pressure using (2/64) disc nozzles. Emulsion sprays were applied in 2 dilutions, 5 and 55 gallons per acre, at 80 and 60 pounds pressure with Teejet nozzles 1.5 and 18 respectively. In 1950 a 4-row boom was used to apply emulsion sprays in dilutions of 20 and 45 gallons per acre; two nozzles[2] per row were used to apply these two dilutions at 65 and 55 pounds pressure respectively. The wettable powder spray applications in 1950 were made at the rate of 45 gallons per acre and at 50 pounds pressure, using a 6-row boom with 1 (Teejet No. 18) nozzle per row. All spray applications above four were applied to small plot subdivisions of the larger treated fields with a pack sprayer using the same type of nozzles and approximately the same rate per acre. The dust applications, during both seasons, were applied with a 4-row self-propelled experimental duster at the rate of 35 to 40 pounds of dust per acre.

DDT was applied at the rate of 1 pound of DDT per acre as a wettable powder spray; also as an emulsion containing 0.75 pound of DDT in dilutions of 5, 20, 45, and 55 gallons of spray per acre, and as a 5 per cent dust using 1.75 to 2 pounds of DDT per acre. Parathion was applied at 0.075 pound per acre as a wettable powder spray and at 0.35 to 0.4 pound as a 1 per cent dust.

METHOD OF SAMPLING AND ANALYSIS.[3]—Lettuce plants were taken for residue analysis from spray plots, where applicable, immediately after the spray had dried and at various intervals after the fourth, fifth, and sixth application and at harvest time for each corresponding plot. Samples from dust plots were taken after the last application and again at harvest. Untreated check plants were not taken at the time of every sampling. These samples were obtained instead at somewhat longer intervals due to the large number of treated samples involved in the study, and because the results of the check analyses were comparatively low and had previously been shown to vary at random with no regular trend.

Each sample for analysis consisted of five lettuce plants of average size taken at random from a plot. The harvest sample was divided into two parts, the lower leaves and the market heads. The lower leaves were the portion of the plant normally left in the field when the grower cuts the crop. Market heads were representative of the lettuce which is placed on the market.

Lettuce samples were first weighed, then chopped into small squares and stripped in benzene. Two and one-half to 5 gallon jars were used for the stripping process in which a carefully measured quantity approximating 1 milliliter of benzene was added for each gram of lettuce. The lettuce and benzene were thoroughly mixed by allowing the jars to revolve on a specially designed rolling machine for at least 10 minutes. After mixing, a portion of the benzene was filtered into 500 milliliter bottles and sent to the laboratory for analysis. Parathion samples were run within 1 or 2 days using the Averell & Norris (1948) colorimetric method while the DDT samples were either run immediately or stored in a

[1] Bolen's Garden Tractor.

[2] Teejet No. 3 and 6.

[3] Thanks are due to Dr. Charles Yager, of the Oswego State Teachers College faculty, for providing suitable facilities for the stripping of the lettuce samples and to Barbara Gast, Julieanne Prager, and William Bradford Bond, of the Cornell Agricultural Experiment Station, for conducting the chemical analyses.

dark cold room, for not more than 2 months, before analysis by a modified Schechter *et al.* (1945) colorimetric method. The final residue determinations were obtained when the analyses of the check samples for each insecticide were separately averaged and then subtracted from the uncorrected residues of treated samples.

The results of the analyses for the 2 seasons are given in tables 1 through 5. Each table lists the residues resulting from two different insecticidal treatments or dilutions. These treatments were applied to adjoining halves of lettuce fields for comparison as to the degree of six-spotted leafhopper control; therefore, the explanatory data given in any one table would apply to both treatments.

WEATHER CONDITIONS.—The precipitation is given in tables 1 through 5 as the amount of accumulated rainfall that occurred during the intervals between the analyses. The two seasons were practically opposite as far as rainfall and temperature were concerned. The combination June, July and August temperature for 1949 was the warmest on record. Rainfall was below normal during July, 1949, but practically normal during August. In 1950, a below normal average temperature was recorded for July and August while the rainfall was above normal during these months.

DDT RESIDUES.—*DDT Wettable Powder Spray.*—During 1949 lettuce plants were taken for analysis from three plots that had been sprayed 4 to 6 times with a spray containing DDT wettable powder and from two plots in 1950 that had received 4 to 5 applications of this material. The results of these analyses, listed under the DDT residue column of tables 1 and 2, indicate that samples taken immediately after the fourth application had residues ranging from 9.1 to 68.3 ppm. The majority of these initial residues progressively decreased until at harvest time, 14 to 25 days later, the market heads had only 0 to 0.37 ppm and the lower leaves 0.38 to 3.62 ppm.

As shown in table 1, the sample taken from replicate 2 on July 28, 1949, was accidentally dusted with 5 per cent DDT by the grower subsequent to the time of the fourth application on July 21. In spite of this the harvest sample from the above plot analyzed only 0.31 ppm on the market heads and 1.22 ppm on the lower leaves. Particular notice should also be given to the decrease of the residue in the case of the sample taken from replicate two on August 2, 1950 (Table 2). The initial deposit was 68.3 ppm on August 1, but decreased to 15.5 ppm on August 2 following 0.57 inches of rain that fell during the late evening of August 1 and the early morning of August 2.

Five applications produced initial residues up to 572 ppm and again the analyses of samples taken at increasing intervals after the final application showed decreasing amounts of DDT to be present. The harvest samples, taken from the plots 11 to 17 days after the final application, have residues of 0.07 to 0.39 ppm on the market heads and 2.34 to 38.5 ppm on the lower leaves.

Six applications were applied in 1949 only and the resulting residues are listed in table 1. The date of the last application was 4 to 6 days prior to harvest. An indication of the danger of excessive residues following late applications was clearly shown by these results as the residues ran as high as 5.42 ppm on the market heads and 66.3 ppm on the lower leaves.

DDT Oil Emulsion Spray.—During the two growing seasons DDT oil emulsion sprays were applied using the same amount of actual insecticide per acre per application but in 4 different spray dilutions. The plots received four applications in 1949 and 4 to 5 applications during 1950. The results of these analyses are given in tables 3 and 4.

The initial residue after four applications ranged from 9.1 to 81.5 ppm. The date of harvest, following four applications, varied from 18 to 33 days after the date of the last application. At this time the market heads showed deposits of DDT ranging from 0 to 0.8 ppm while the lower leaves had 0.1 to 5.56 ppm. The effect of rain soon after application was again shown by the samples taken on August 4, 1950 (Table 4). Immediately after the fourth application on August 3 the sample from the dilute spray plot was shown to have a DDT deposit of 79.9 ppm, while the lettuce from the concentrated spray plot analyzed 63 ppm. One day later, and after 0.22 inches of rain, the residue had decreased to 51 and 42.7 ppm respectively.

During 1950 samples were taken on

Table 1.—DDT and parathion residues on Iceberg lettuce in parts per million when the insecticides were applied as wettable powder sprays at the rate of 1 pound of DDT and 0.075 pound of parathion per acre per application, 1949.[1]

Replicate	Date Sample Taken	Accumulated Rainfall in Inches	Days Since Last Application	Days Before Harvest	Insecticide Residues	
					DDT	Parathion
			Four Applications			
1[2]	7/14		0	18	9.1	0.71
2[3]	7/21		0	20	19.0	0.45
3[4]	8/10		0	14	40.	0.03
1	7/21	0.63 (7/14–7/21)	7	11	2.71	0.07
2	7/28	0.46 (7/21–7/28)	7	13	30.3[5]	0.0
1	7/28	0.46 (7/22–7/28)	14	4		0.0
2	8/4	0.13 (7/29–8/4)	14	6	3.11	0.0
1	8/1	1.22 (7/14–8/1)	18	0	0.0	0.0 (mkt. heads)
					0.62	0.31 (lower lvs.)
2	8/10	0.64 (7/21–8/10)	20	0	0.31	0.0 (mkt. heads)
					1.22	0.27 (lower lvs.)
3	8/24	0.49 (8/10–8/24)	14	0	0.37	0.0 (mkt. heads)
					3.62	0.0 (lower lvs.)
			Five Applications			
1	7/21		0	11	55.	3.31
2	7/28		0	13	25.4	2.04
1	7/28	0.46 (7/21–7/28)	7	4	3.57	0.0
2	8/4	0.13 (7/28–8/4)	7	6	9.35	0.03
1	8/1	0.59 (7/21–8/1)	11	0	0.07	0.0 (mkt. heads)
					2.69	0.01 (lower lvs.)
2	8/10	0.18 (7/28–8/10)	13	0	0.39	0.0 (mkt. heads)
					6.11	0.0 (lower lvs.)
			Six Applications			
1	7/28		0	4	30.7	0.46
2	8/4		0	6	100.	1.08
1	8/1	0.13 (7/28–8/1)	4	0	5.42	0.03 (mkt. heads)
					20.9	0.25 (lower lvs.)
2	8/10	0.05 (8/4–8/10)	6	0	1.9	0.0 (mkt. heads)
					66.3	0.03 (lower lvs.)

[1] 2 lbs. 50% DDT and 0.5 lb. 15% parathion per 55 gals. of spray per acre.
[2] Applic. dates; 4 applics.—6/22, 6/30, 7/7, 7/14; 5th applic. 7/21; 6th applic 7/28.
[3] Applic. dates; 4 applics.—6/30, 7/7, 7/14, 7/21; 5th applic. 7/28; 6th applic. 8/1.
[4] Applic. dates; 4 applics.—7/21, 7/28, 8/4, 8/10.
[5] Accidentally dusted with 5% DDT by the grower.

various dates after the fourth and fifth applications until harvest and, in general, showed successively smaller deposits of DDT to be present. The results for five applications, as given in table 4, denotes residues as high as 192 ppm to be present immediately after the fifth application. The deposits rapidly became smaller and at the time of harvest, 20 to 28 days later, the market heads had low residues of 0.05 to 0.53 ppm and the lower leaves 0.13 to 2.59 ppm.

DDT Dust.—DDT dust was applied to individual lettuce plots 3 to 5 times and the interval from the date of the last application until harvest ranged from 16 to 24 days. The residues given in table 5 disclose that the deposits immediately after the last application were as high as 61.9 ppm. Harvest samples showed 0 to 0.47 ppm on the market heads and 0.59 to 2.16 ppm on the lower leaves.

PARATHION RESIDUES.—*Parathion Wettable Powder Spray.*—The results of the parathion wettable powder spray analyses are given in tables 1 and 2 along with the residues of samples from plots treated with DDT wettable powder spray. Because of the small amount of actual parathion applied in one application per acre (0.075 pound) in the wettable powder sprays even the initial deposit after 4 applications was low, ranging from 0.03 to 2.2 ppm. Residues on the harvest sam-

Table 2.—DDT and parathion residues on Iceburg lettuce in parts per million when the insecticides were applied as wettable powder sprays at the rate of 1 pound of DDT and 0.075 pound of parathion per acre per application, 1950.[1]

Replicate	Date Sample Taken	Accumulated Rainfall in Inches	Days Since Last Application	Days Before Harvest	Insecticide Residues	
					DDT	Parathion
			Four Applications			
1[2]	7/17		0	25	58.7	2.20
2[3]	8/1		0	24	68.3	1.85
2	8/2	0.57 (8/1–8/2)	1	23	15.5	0.31
1	7/24	1.02 (7/17–7/24)	7	18	5.88	0.32
1	7/25	0.00 (7/25)	8	17	3.49	0.28
2	8/9	0.22 (8/3–8/9)	8	16	2.24	0.10
1	7/31	0.54 (7/26–7/31)	14	12	0.84	0.0
2	8/16	0.10 (8/10–8/16)	15	9	0.54	0.0
2	8/23	0.96 (8/17–8/23)	22	2	1.12	0.0
1	8/11	2.35 (7/17–8/11)	25	0	0.05	0.0 (mkt. heads)
					1.80	0.0 (lower lvs.)
2	8/25	2.17 (8/1–8/25)	24	0	0.05	0.0 (mkt. heads)
					0.38	0.0 (lower lvs.)
			Five Applications			
1	7/25		0	17	105.	2.91
2	8/9		0	16	572.	1.06
1	8/1	0.60 (7/25–8/1)	7	10	9.48	0.0
2	8/16	0.10 (8/9–8/16)	7	9	7.97	0.0
2	8/23	0.96 (8/17–8/23)	14	2	10.3	0.0
1	8/11	1.33 (7/25–8/11)	17	0	0.20	0.0 (mkt. heads)
					2.34	0.01 (lower lvs.)
2	8/25	1.38 (8/9–8/25)	16	0	0.35	0.0 (mkt. heads)
					38.5	0.0 (lower lvs.)

[1] 2 pounds 50% DDT and 0.5 pound 15% parathion per 45 gals. of spray per acre.
[2] Applic. dates: 4 applic.—6/26, 7/3, 7/10, 7/17; fifth applic. 7/25.
[3] Applic. dates: 4 applic.—7/10, 7/17, 7/25, 8/1; fifth applic. 8/9.

ples, taken 14 to 25 days after the final application, were only as high as 0.31 ppm on the lower leaves while no residue was found on the market heads. As in the case of the DDT sprays, 0.57 inches of rain was probably the main factor in decreasing the residue from 1.85 ppm on August 1, 1950, to 0.31 ppm on August 2. It was also suspected that the high rate of volatility of parathion aided in the rapid reduc-

Table 3.—DDT residue on Iceberg lettuce in parts per million when emulsion sprays were applied in two dilutions at the rate of 0.75 pound of DDT per acre per application, 1949.

Replicate	Date Sample Taken	Accumulated Rainfall in Inches	Days Since Last Application	Days Before Harvest	DDT Residues	
					Dilute[1]	Concentrated[2]
1[3]	7/19		0	19	15.3	66.3
2[4]	7/26		0	18	57.	9.1
1	8/7	1.04 (7/19–8/7)	19	0	0.0	0.0 (mkt. heads)
					0.31	0.52 (lower lvs.)
2	8/13	0.25 (7/26–8/13)	18	0	0.0	0.0 (mkt. heads)
					0.72	0.87 (lower lvs.)

[1] 1.5 qts. 25% DDT oil emulsion per 55 gals. of spray per acre.
[2] 1.5 qts. 25% DDT oil emulsion per 5 gals. of spray per acre.
[3] Applic. dates; 4 applic.—6/27, 7/5, 7/12, 7/19.
[4] Applic. dates; 4 applic.—7/5, 7/12, 7/19, 7/26.

tion of parathion residue during the 24-hour interval. (Replicate 2, Table 2).

Samples taken immediately after the last of 5 applications were found to have deposits varying from 1.06 to 3.31 ppm; subsequently at harvest time, 11 to 17 days after the fifth application, the market heads were found to have no detectable residue and only 0.01 ppm on the lower leaves.

The results of analyses after a series of 6 applications, the last being 4 to 6 days prior to harvest, are given in table 1. Residues recovered immediately after the sixth application gave maximum deposits of 1.08 ppm. The deposits on the harvest samples showed the market heads had a maximum residue of 0.03 ppm while the lower leaves analyzed 0.25 ppm.

Parathion Dust.—The residues following 3 to 5 applications of parathion dust to lettuce plots are given in table 5. Deposits, ranging from 2.18 to 13.1 ppm after the final dust application, were considerably higher than any of the residues resulting from parathion wettable powder spray treatments. The main reason was probably that only 0.075 pound of parathion was applied per application of the wettable powder spray as compared with 0.35 to 0.4 pound of actual insecticide per application of dust. Regardless of the higher initial deposit the residue had practically disappeared after 16 to 24 days, when the lettuce was harvested. The market heads, at that time were found to show deposits of 0 to 0.14 ppm and the lower leaves 0 to 0.02 ppm.

DISCUSSION.—When the lettuce residue experimental work was planned it appeared particularly desirable to be able to consider those factors which might have a bearing in determining the amount of DDT and parathion residue which may be present at harvest. The following are the main factors that were considered; each factor would have numerous subdivisions and all might be closely correlated, one to another: 1) The magnitude of the combined deposits that together form the final deposit immediately after the last application; 2) the interval of time between the last application and harvest; 3) the amount of accumulated rainfall from the time the final spray was applied until harvest.

The above factors are somewhat in accord with those listed by other workers. Carter (1948) expressed the opinion that the amount of residue on crops would depend on the weight of the crop per unit area, the amount of insecticide applied per unit area, the time between sampling and the last treatment, and the total effect from growth and weathering. Robinson (1949 b) found the harvest residue on vegetables was influenced by the concentration and formulation of the dusts or sprays used, the amount of insecticide applied, the interval between the last application and harvest, and the surface area of the food crop in relation to its weight.

Various conclusions have been drawn previously as to the relationship between the DDT residues at the time of the last application, or at harvest, and the number of applications; also to the length of the period between the last application and harvest, and the correlation of these factors with the harvest time residue. Allen & Berck (1950) showed that the DDT harvest residues on celery increased with the rate of application and with a decrease in the time from the date of the last application to harvest. In applications of DDT wettable powder sprays on gooseberries and currants Allen *et al.* (1950) concluded there was no recognizable connection between DDT residues on harvested fruits and the period between the last application to harvest or to the precipitation during this period. Brunson & Koblitsky (1950) stated that repeated applications of DDT wettable powder sprays increased residues on peach leaves with each application, but for the most part the workers could find no clear relationship between the length of the interval between the last application and harvest and the harvest residue on the fruits. Decker (1946) in a review of the data available at that time expressed the opinion that the elapsed time between the last application and harvest was of more consequence than the number of applications or amount of DDT used. Residues on alfalfa were found by Eden & Arant (1948) to increase with the number of DDT dust applications and then to decrease over a 40-day period following the final application until they became equal, regardless of the number of applications at that rate. Ginsburg *et al.* (1949) found that the amount of rainfall had a bearing on the harvest residue but that the relationship

Table 4.—DDT residue on Iceburg lettuce in parts per million when emulsion sprays were applied in two dilutions at the rate of 0.75 pound of DDT per acre per application, 1950.

Replicate	Date Sample Taken	Accumulated Rainfall in Inches	Days Since Last Application	Days Before Harvest	DDT Residue	
					Dilute[1]	Concentrated[2]
			Four Applications			
1[3]	7/12		0	27	81.5	71.1
2[4]	8/3		0	33	79.9	63.0
2	8/4	0.22 (8/3–8/4)	1	32	51.	42.7
1	7/19	0.93 (7/12–7/19)	7	20	5.28	4.38
2	8/8	0.00 (8/5–8/8)	5	28	12.49	5.88
1	7/26	0.38 (7/20–7/26)	14	13	2.62	2.99
2	8/15	0.0 (8/9–8/15)	12	21	1.60	0.57
1	8/2	1.11 (7/27–8/2)	21	6	0.13	0.83
2	8/23	1.06 (8/16–8/23)	20	13	0.81	0.34
1	8/8	2.64 (7/12–8/8)	27	0	0.50	0.80 (mkt. heads)
					1.60	5.56 (lower lvs.)
2	9/5	4.44 (8/3–9/5)	33	0	0.03	0.0 (mkt. heads)
					0.10	0.29 (lower lvs.)
			Five Applications			
1	7/19		0	20	34.1	31.8
2	8/8		0	28	150.0	192.0
1	7/26	0.38 (7/19–7/26)	7	13	6.22	3.32
2	8/15	0.0 (8/8–8/15)	7	21	8.31	8.55
1	8/2	1.11 (7/27–8/2)	14	6	0.66	0.71
2	8/23	1.06 (8/16–8/23)	15	13	1.44	1.68
1	8/8	1.71 (7/19–8/9)	20	0	0.53	0.49 (mkt. heads)
					2.59	2.09 (lower lvs.)
2	9/5	4.22 (8/8–9/5)	28	0	0.11	0.05 (mkt. heads)
					0.29	0.13 (lower lvs.)

[1] 1.5 qts. 25% DDT oil emulsion per 45 gals. of spray per acre.
[2] 1.5 qts. 25% DDT oil emulsion per 20 gals. of spray per acre.
[3] Applic. dates—6/21, 6/28, 7/5, 7/12; fifth applic. 7/19.
[4] Applic. dates—7/12, 7/19, 7/26, 8/3; fifth applic. 8/8.

Table 5.—DDT and parathion residues on Iceburg lettuce in parts per million when the insecticides were applied as 5 and 1 per cent dusts, respectively, 1949–1950.[1]

Replicate	Date Sample Taken	Accumulated Rainfall in Inches	Days Since Last Application	Days Before Harvest	Insecticide Residue	
					DDT	Parathion
			1949			
1[2]	7/11		0	18		3.8
2[3]	7/25		0	16	61.9	9.3
1	7/29	1.09 (7/11–7/29)	18	0		0.0 (mkt. heads)
						0.0 (lower lvs.)
2	8/10	0.34 (7/25–8/10)	16	0	0.0	0.0 (mkt. heads)
					1.70	0.0 (lower lvs.)
			1950			
1[4]	7/14		0	24	6.68	2.18
2[5]	8/7		0	21	61.2	13.1
1	8/7	2.35 (7/14–8/7)	24	0	0.36	0.0 (mkt. heads)
					2.16	0.02 (lower lvs.)
2	8/28	1.77 (8/7–8/28)	21	0	0.47	0.14 (mkt. heads)
					0.59	0.0 (lower lvs.)

[1] Dusts applied at the rate of 35 to 40 pounds per acre.
[2] Applic. dates—6/17, 6/23, 6/28, 7/5, 7/11.
[3] Applic. dates—7/5, 7/8, 7/13, 7/18, 7/25.
[4] Applic. dates—6/23, 6/30, 7/7, 7/14.
[5] Applic. dates—7/20, 7/26, 8/7.

was not always proportional. Gunther *et al.* (1946) determined by chemical and biological means the weathering and decomposition of DDT over a 3-month period and reported that two heavy rains during the latter part of the study did not demonstrate any effect upon the magnitude of the DDT deposits. Hoskins (1949) stated that the loss of deposit due to weathering, volatilization and other processes was strongly affected by time. Manalo *et al.* (1946) found that DDT dusts and sprays left varying amounts of residue which did not bear any positive relationship to the number of applications. It was noted by Poos *et al.* (1950) in results of forage crops residue studies that the amount of residue remaining at harvest was not always proportional to the amount of DDT applied to the crop if no run-off was permitted.

As to the factors affecting the amount of parathion residue data presented by Barnes *et al.* (1950) showed higher residues on peaches 7 to 14 days after applications of 2 pounds of actual parathion as compared to 1 pound, but after 30 days the deposits were approximately equal. Surface residues on peaches were stated to be 4 to 15 fold higher than on apples or pears, possibly due to the more retentive surface of peaches. Johansen & Breakey (1949) reported analyses that showed only fractional differences in the parathion residues at harvest on raspberries when three spray schedules, each consisting of three applications, were ceased 1, 3 and 5 weeks prior to harvest. For red-banded leaf roller control King *et al.* (1948) applied sprays containing approximately 0.6 and 0.25 pound of actual parathion and 3 weeks after application all residues were shown to be negligible and nearly equal. Walker (1950) reported that increased concentrations of parathion applied to peaches gave higher residues and that the magnitude of the harvest deposits were proportional to the length of time between the date of application and harvest; however, in applications to apples this conclusion was not found to be true. Westlake & Fahey (1950) found that an increase in the parathion spray concentration or a decrease in the time interval between the last spray and harvest often did result in heavier residues.

In attempting to correlate the DDT data pertaining to residues on other crops it was noticed that in the majority of the cited studies the interval between the date of the last application and harvest was usually more than a month. Under these circumstances the residues might tend to become nearly equal and remain at a somewhat low level. This may explain the reason why, in some cases, there was no relationship found in the length of the interval between the last application and harvest residue. The equalization of DDT residues was previously pointed out by Eden & Arant (1948) and further confirmed by the curves and tables prepared by Sloan *et al.* (1951)[1] showing the effect of growth and weathering on the apparent reduction of DDT residues on lettuce.

Under conditions of the present residue study the results of the various analyses, taken immediately after the fourth through sixth application of DDT wettable powder spray and the fourth and fifth application of DDT oil emulsion, spray, would generally seem to indicate an increase in the initial deposit of DDT with each additional application above 4. On the other hand, there was less consistency between the magnitude of parathion wettable powder spray deposits taken from samples analyzed immediately after each application above 4 and the total number of previous applications; however, this was to be expected because of the more complete loss of the low initial parathion residue during the weekly intervals between applications.

It was also found that DDT spray residues generally tended to be higher at the time of harvest when there was an increase in the number of applications, which, at the same time, would mean a decrease in the interval between the last application and harvest. Parethion harvest residues were less consistent even when 6 applications were applied; the last application being only 4 to 6 days prior to harvest.

When considering the first factor mentioned at the beginning of the discussion, the relationship between the magnitude of the insecticide deposit determined immediately after the last application and the harvest residue, the following was noted: 64 per cent of the DDT wettable powder, 64 per cent of the parathion wettable powder, and 50 per cent of the DDT oil emulsion spray samples receiving an equal

number of applications, did show a positive relationship between the magnitude of the original deposit after the last application and the amount of residue at harvest.

In regard to the second factor listed, the interval of time between the last application and harvest and its relation to the harvest residue, a survey of the data presented in tables 1 through 4 revealed the following information: It was found that 100 per cent of the lettuce samples taken at harvest time from plots which had received a comparable number of DDT oil emulsion spray applications showed an increase in residue when there was a decrease in the time interval between the last application and harvest. This same factor has less bearing on DDT and parathion wettable powder sprays and was found to apply to only 27 per cent and 36 per cent of the harvest samples, respectively.

The third factor, the amount of accumulated rain during the interval between the last application and harvest, was found to be important in the present study. Harvest samples taken from plots that received an equal number of DDT spray applications were found to have lower residues when there was more rainfall; such was the case in 100 per cent of the harvest samples taken from plots treated with DDT oil emulsion sprays and 64 per cent of the analyses from DDT wettable powder spray plots. The higher accumulated rainfall effected lower residues in only 18 per cent of the parathion wettable powder spray harvest samples; however, other causes reduced the parathion residue so much that the effect of rain could easily have been obscured.

It has already been pointed out that rain within 1 day after the final application of DDT or parathion spray did apparently reduce the insecticide deposit on lettuce; also, it was shown above that the accumulated rainfall, occurring within the 33 days limit of the experiments, definitely affected the amount of DDT spray harvest residue. Precipitation soon after application may have a greater effect than that occurring nearer the date of harvest on the amount of residue recovered at harvest time.

The immediate effect of rain upon DDT was pointed out by Fennah (1945) who exposed DDT spray deposits on slides to 1.6 inches of intermittent rain for periods up to 2 days and noted that there was a progressive erosion of the aggregates. It was also indicated that DDT emulsion deposits, soon after application, may be eroded before they have crystallized out of solution. Hadaway & Barlow (1949) noted that 0.87 inches of rain during the first 24 hours after an application of DDT wettable powder spray washed off most of the deposit on exposed plants.

The results of the lettuce residue analyses show that DDT and parathion residues are slight at the time of harvest when the date of the last application is at least 2 weeks previous. This would be the latest date that might be necessary to protect the lettuce plants from six-spotted leafhopper attack and the resulting inoculation of the lettuce yellows virus. Because of the length of the incubation period of the virus in the plant, which is a minimum of 14 days for lettuce near the marketable stage, there is little danger of the disease symptoms being evident at harvest time if inoculation occurs 2 weeks prior to harvest.

An average of the weights of all of the harvest samples showed that the lower leaves represented some 32 per cent of the total weight of the lettuce plant at the time of harvest. Since most of the residue remaining at harvest time is deposited on the lower leaves, as evidenced from the analyses, and this portion of the plant is left in the field by the grower, the chance of excessive residue is further reduced.

SUMMARY AND CONCLUSIONS.—An extensive study was made of insecticide residues on lettuce over a period of 2 years. Residue analyses were made at the time of the last application and at intervals until harvest on lettuce plants treated with various formulations of parathion or DDT which were applied.

Spray deposits of DDT immediately following the last application were usually larger in those plots receiving a greater number of earlier sprays. Parathion was less consistent, probably because of the more complete disappearance of the accumulated deposits from the earlier sprays. The residues at harvest followed the same pattern.

For the samples from plots that received an equal number of spray applications, it was found in the majority of the tests for both parathion and DDT that a

higher final residue at the time of the last application resulted in a subsequently higher harvest residue.

A shorter interval between the last application and harvest, for those samples that received an equal number of applications, increased the harvest residue consistently when DDT oil emulsion was used, and less consistently with DDT and parathion wettable powder spray treatments.

Rain within a day after application caused a marked reduction of the deposits of both DDT and parathion sprays. Greater accumulated rainfall between the last application and harvest, for those samples that received a similar number of applications, gave lower harvest residues in most of the DDT spray plots, but was less consistent in the parathion spray plots where losses from other sources were greater.

Most of the residues at harvest were found on the lower leaves which are left in the field when the lettuce heads are cut for market. The highest DDT residue found on market heads when applications were continued up to 11 days from the harvest date was less than 1 ppm. When DDT treatments were continued as late as 4 days before harvest, however, residues up to 5.4 ppm occurred on the market heads. The highest parathion residue found was 0.14 ppm, which occurred on a sample treated only 4 days before harvest.

LITERATURE CITED

Allen, W. R., and B. Berck. 1950. DDT residues on celery resulting from dust treatments for control of the tarnished plant bug. Sci. Agr. **30:** 375–9.

Allen, W. R., H. P. Richardson, B. Berck, and A. G. Robinson. 1950. DDT residues on currants and gooseberries. Sci. Agr. **30:** 380–3.

Ashdown, Donald, and T. C. Watkins. 1948. Control of the lettuce yellows disease in New York. JOUR. ECON. ENT. **41**(2): 252–8.

Averell, P. R., and M. V. Norris. 1948. Estimation of small amounts of 0,0-diethyl-0, p-nitrophenyl thiophosphate. Analytical Chemistry **20**(8): 753.

Barnes, M. M., G. E. Carman, W. H. Ewart and F. A. Gunther. 1950. Fruit surface residues of DDT and parathion at harvest. Advn. Chem. Ser. **1:** 112–6.

Bowser, P. H. 1946. Effects of DDT on cabbage maggot, on radishes, and on aster yellows and the leafhopper of head lettuce. A progress report. In Mich. Agr. Exp. Sta. Quart. Bul. **28:** 194–200.

Brunson, M. H., and Louis Koblitsky. 1950. A study of DDT deposits on peach foliage and fruit treated for control of the oriental fruit moth. U.S.D.A.—B.E.P.Q. E-809.

Carter, R. H. 1948. DDT residues in agricultural products. Jour. Ind. and Eng. Chem. **40**(4): 716–7.

Coons, G. H. 1922. Diseases of field and vegetable crops in the United States in 1921. In U. S. Plant Ind. Bur. Plant Disease Reporter, Suppl. **22:** 409.

Decker, G. C. 1946. Agricultural applications of DDT, with special reference to the importance of residues. JOUR. ECON. ENT. **39**(5): 557–62.

Eden, W. G., and F. S. Arant. 1948. DDT residues on alfalfa. JOUR. ECON. ENT. **41**(3): 383–7.

Fennah, R. G. 1945. Preliminary tests with DDT against insect pests of food crops in the Lesser Antilles. Tropical Agr. **22**(12): 222–6.

Ginsburg, J. M., R. S. Filmer, J. P. Reed and A. R. Paterson. 1949. Recovery of parathion, DDT and certain analogs of dichlorodiphenyl-dichloroethane from treated crops. JOUR. ECON. ENT. **42**(4): 602–11.

Gunther, F. A., D. L. Lindgren, M. I. Elliot, and J. P. LaDue. 1946. Persistence of certain DDT deposits under field conditions. JOUR. ECON. ENT. **39**(5): 624–7.

Hadaway, A. B., and F. Barlow. 1949. Further studies on the loss of insecticide by absorption into mud and vegetation. Bul. Ent. Res. **40**(3): 323–43.

Hoskins, W. M. 1949. Deposit and residue of recent insecticides resulting from various control practices in California. JOUR. ECON. ENT. **42**(6): 966–73.

Johansen, Carl and E. P. Breakey. 1949. Accumulated residues of insecticides tested to control orange tortrix on red raspberries. JOUR. ECON. ENT. **42**(3): 543.

King, H. L., R. Hutson and T. H. Farr. 1948. The control of red-banded leaf roller with parathion. JOUR. ECON. ENT. **41**(6): 976–7.

Kunkel, L. O. 1925. Insect transmission and host range of aster yellows. Sci. Ser. **62:** 524.

Linn, M. B. 1940. The yellows disease of lettuce and endive. Cornell Univ. Agr. Exp. Sta. Bul. **742.**

Manalo, C. D., R. Hutson and E. J. Benne. 1946. DDT Residues on fruit and vegetables. In Mich. Agr. Exp. Sta. Quart. Bul. **28**(4): 272.

Pepper, Bailey B., and C. M. Haenseler. 1939. Pyrethrum and derris as a control for the six-spotted leafhopper, a vector of lettuce yellows. JOUR. ECON. ENT. **32**(2): 291–6.

Poos, F. W., T. N. Dobbins and R. H. Carter. 1950. Sampling forage crops treated with organic insecticides for determination of residues. U.S.D.A.—B.E.P.Q. E-793.

Reiber, H. G., and E. M. Stafford. 1946. DDT deposit and residues on olives, grapes, cabbage, green beans and peas. In Calif. Agr. Expt. Sta. Circ. **365:** 104–8.

Robinson, R. H. 1949a. Spray residues and precautions relative to handling new spray materials. Oreg. State Hort. Soc. Proc. **41:** 34–7.

Robinson, R. H. 1949b. DDT residue on vegetables. Oreg. Agr. Exp. Sta. Info. Circ. 158.
Schechter, M. S., S. B. Soloway, R. A. Hayes and H. L. Haller. 1945. Colorimetric determination of DDT and related compounds. Analyt. Chem. 17(11): 704–9.
Smith, Floyd F., L. P. Ditman and L. D. Goodhue. 1945. Experiments with aerosols against some pests of truck crops. JOUR. ECON. ENT. 38(2): 189–96.
Walker, K. C. 1950. Parathion spray residue on soft fruits, apples, and pears. Advn. Chem. Ser. 1: 123–7.
Westlake, W. E., and J. E. Fahey. 1950. DDT and parathion spray residues on apples. Advn. Chem. Ser. 1: 117–22.

Factors Affecting the Loss of DDT and Parathion Residues on Lettuce

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The decrease of insecticide residue on any plant can be attributed to two main factors, growth and weathering. The relative importance of each factor is dependent chiefly upon the rate of growth of the plant to which the insecticide has been applied, the nature of the insecticide, and the length of time between the last application and harvest. A better knowledge of the magnitude of the effects of growth or weathering would permit more accurate and dependable predictions of harvest time residues.

It is evident that growth alone can be a very important factor in the apparent reduction of insecticide residue, even though this reduction is due only to an increase in weight of the plant, and not an actual loss of the insecticide deposit. When residue determinations are expressed on the basis of parts per million by weight, or one part of insecticide per million parts of plant material, it becomes obvious that the original residue on a fast growing plant would reach low levels more rapidly than on a slow growing plant. The effect of growth upon the insecticide residues on a particular crop constitutes an apparent reduction which would remain proportionally the same regardless of the insecticidal material applied. The loss of insecticide deposit due to the many phenomena that are grouped under the general heading of weathering (sunshine, wind, rain, volatility and others) results in an actual decrease of deposit from the plant. The magnitude of the actual loss of insecticide as caused by weathering would vary for the different insecticides and formulations, with the prevailing weather conditions, and with the retentiveness of the plant surfaces to which the treatments were applied.

Growth has long been recognized as an important factor in the reduction of any insecticidal residue and is frequently mentioned as such in publications pertaining to residue studies; however, little attempt has been made to evaluate its effect quantitatively. Fahey & Rusk (1939) reported residues of lead arsenate, phenothiozine, and nicotine-bentonite on apples were affected by the rate of growth of each treated fruit and the amount of weathering to which the apples were exposed. Their calculations showed an average daily increase in area of 1 square centimeter per apple per day. Stanley (1945) calculated the increase in leaf area of bunch beans and burley tobacco and showed that beans grew at a daily rate of 12.67 per cent and tobacco at 6.77 per cent. The rapidity of the decrease in arsenical residue was shown by Hamilton (1929) to be proportional to the rate of increase of the leaf area. It was shown from data on the increase in surface area and volume of apples that growth was more important in the reduction of residue when it increased rapidly, but when growth was slow weathering was more important. Webster (1950) considered the increase in size of fruits to be of more consequence than weathering in the reduction of insecticide residue on apples and peaches grown in the irrigated regions of the Pacific Northwest.

As to the effect of weathering on DDT residues Arant (1948) found that the combined action of weathering on peanut vines for 4 to 5 weeks, along with 6 inches of rain, and the bailing process, removed most of the DDT residue from peanut hay. Burgess & Sweetman (1949) reported that high temperature and high humidity caused a more rapid decrease in

the effectiveness of DDT than did low temperature and low moisture. Sweetman (1945) suggested that temperature, moisture, and light may all be important factors in influencing the residual effectiveness of DDT against field pests.

Dustan *et al.* (1947) found that the exposure of DDT residue to air currents for periods up to 6 days had little influence in reducing its effectiveness. Fleck (1944) concluded that the loss of DDT spray deposits by volatilization occurred too slowly to be of importance. Sunlight and ultra-violet light are known to affect deposits of DDT deleteriously, as shown in experiments by Chisholm & Koblitsky (1947); Fleck (1949); Gahan *et al.* (1945); Goddin & Swingle (1945); Gunther (1945); Gunther *et al.* (1948); Linquist *et al.* (1946); Wichmann *et al.* (1946); and others.

There seemed to be but little information concerning the factors involved in the breakdown of parathion residues, although there was general agreement that they decreased much more rapidly than those of DDT. The majority of the reported residue studies on parathion involved only the total reduction due to all factors; however, it is known that weathering over a relatively short period of time will bring about a fairly rapid volatilization of this insecticide; also hydrolysis by plant enzymes and other agencies has been suggested.

The DDT and parathion residue study on lettuce, conducted by the authors during the 1949 and 1950 growing seasons, presented an excellent opportunity to evaluate the effect of growth quantitatively, and to show the importance of growth and weathering on the reduction and loss of DDT or parathion spray residues on a fast growing crop. Only the total effect of weathering, and not its component factors, was considered in the present study.

PROCEDURE.—Residue samples used in the calculations to follow were obtained from lettuce plots that were treated with DDT or parathion sprays for six-spotted leafhopper control. DDT was applied as a wettable powder spray at the rate of 1 pound per acre and as an oil emulsion spray at 0.75 pound of DDT in 2 spray dilutions, 20 and 45 gallons per acre. Parathion wettable powder spray was applied using 0.075 pound of parathion per acre. Four to six applications of all sprays were made at weekly intervals beginning as soon as the lettuce plants had emerged from the ground. Samples were taken and analyzed at approximate weekly intervals after the fourth to sixth application until harvest from two replicates of each treatment that received similar applications of DDT or parathion sprays. As shown under the actual residue columns of tables 1 through 3, these analyses were calculated to ppm and to micrograms per 5 lettuce plants. These same residue samples were among those employed in the DDT and parathion residue studies reported previously by Sloan *et al.* (1951);[1] therefore, the experimental and analytical procedure as discussed in the latter article also applied to the present study.

The actual residues of DDT or parathion sprays used in the calculations to follow, are identical with some of those previously reported except for the harvest sample residues. It will be recalled from the previous paper that the lettuce harvest samples were divided into two parts, the lower leaves and the market heads, so as to duplicate more closely actual field conditions. For the purpose of the present study it was necessary to combine the results of the two harvest samples to obtain the insecticide residue on the whole plant, and in so doing corrections were made to compensate for the double error thus incurred.

GROWTH DETERMINATIONS.—To determine the magnitude of growth it became necessary to plot a growth curve for Iceberg lettuce. Lettuce plants were taken at increasing stages of growth until harvest time from 12 different fields during the growing seasons of 1949 and 1950. The weights of these plants were obtained, in most cases, in connection with samples taken for residue analyses but some plants were secured in 1949 before the analyses were begun. At each date of sampling an average weight was determined for the 5 to 30 plants taken on that date. In order to bring the plant weights, obtained for different intervals before harvest from the various fields, to the same basis each weight was expressed as a percentage of the final harvest weight of lettuce plants taken from that particular field. The growth of lettuce, expressed as a percentage of the final harvest weight, was plotted against the days before the date of harvest. The resulting growth curve (Fig. 1) was easily drawn by eye

to correspond closely to some 50 points.

The harvest weights of plants taken from different fields did vary, but the weights at corresponding stages of growth expressed as percentages of their respective harvest weight varied little more than did individual samples taken from the same field and at the same time; similarly, there was close agreement between the two seasons in spite of different climatic conditions. This tendency of growth to follow a constant trend, regardless of seasonal variation, would make predictions of harvest time residues based on growth reasonably accurate.

Note in figure 1 that the plant weight at any given time expressed as a percentage of the harvest weight would also be the percentage of the residue remaining at harvest on the weight basis (ppm) if the insecticide was applied on that date; this would be assuming there was no weathering, and the only source of apparent reduction were the increase in the weight of the lettuce plant. For the same total quantity of insecticide, the residue on the weight basis is inversely proportional to the weight of the lettuce. For example, if the application is made 20 days prior to harvest the growth curve shows that the plant has completed approximately 10 per cent of its total growth. The weight will increase from 10 to 100 per cent of its final value between the date of application and harvest and the residue will correspondingly decrease from 100 to 10 per cent of its value immediately after the application.

For the purpose of studying the importance of growth on the apparent reduction of DDT or parathion residues on lettuce calculations were made using the lettuce growth curve (Fig. 1) and the actual spray residue data (Tables 1, 2 and 3). In any one replicate or series of analyses the percentage of weight increase, from the time the residue sample was taken immediately after the last spray application to each of the later dates of sampling, could be determined from the growth curve. The percentage of weight increase was also the percentage of apparent reduction in ppm due to growth. The preceding calculations were applied to the DDT and parathion spray residue data and the results are given under the growth column of tables 1, 2 and 3.

The percentages of residue loss due to growth that could be expected to occur

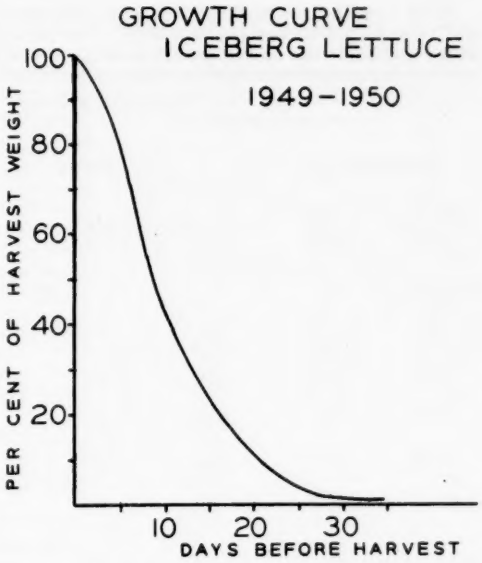

FIG. 1.—Growth curve for Iceberg 456 lettuce, 1949–1950, Oswego County, N. Y.

during the final 2 weeks before harvest were also determined from the growth curve and these results, identical for all treatments, are graphically portrayed in figure 2 by the dashed lines.

WEATHERING DETERMINATIONS.—In order to compare the losses of DDT or parathion spray residue that were due to growth and weathering, and to show the differences graphically, it was necessary

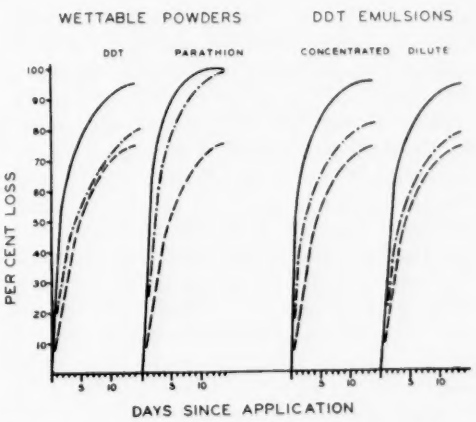

FIG. 2.—Curves denoting the decreases of DDT and parathion spray residues that would result during the final 2 weeks prior to harvest from an apparent loss due to growth, an actual loss because of weathering, and the combined action of growth and weathering. (The dashed lines represent growth, dot-dash lines weathering, and the solid lines the combined effect of growth and weathering.)

Table 1.—The actual residue in ppm and micrograms per 5 lettuce plants at increasing intervals after 4 to 6 applications per plot of DDT or parathion wettable powder sprays; also the percentages of the apparent loss due to growth and the actual loss of insecticide deposit from weathering, 1949.[1]

Time in Days		Percentage Loss			Actual Residue			
		Weathering[3]			PPM		Micrograms per 5 Plants	
Before Harvest	Since Applic.	Growth[2]	DDT	Para.	DDT	Para.	DDT	Para.
				Four Applications				
Replicate 1								
18	0	0	0	0	9.1	0.71	6,944	450
11	7	60	54	66	2.71	0.07	3,255	152
4	14	83		98		0.0		8
0	18	85	95	100	0.08	0.0	333	0
				Five Applications				
11	0	0	0	0	55.0	3.31	105,769	7,440
4	7	55	91	100	3.57	0.0	9,868	0
0	11	62	93		1.93	0.0	7,621	0
				Six Applications				
4	0	0	0	0	30.7	0.46	82,179	1,549
0	4	17	39	84	12.5	0.06	50,110	256
				Four Applications				
Replicate 2								
20	0	0	0[4]	0		0.45		136
13	7	66	0	100	30.3	0.0	29,383	0
6	14	86	75	100	3.11	0.0	7,222	0
0	20	90	93	12	0.65	0.03	2,181	120
				Five Applications				
13	0	0	0	0	25.4	2.04	21,897	1,828
6	7	58	5	98	9.35	0.03	20,734	41
0	13	70	46	100	3.65	0.0	11,825	0
				Six Applications				
6	0	0	0	0	100	1.08	200,760	1,592
0	6	29	75	100	12.1	0.0	50,379	0

[1] 2 lbs. 50% DDT and 0.5 lb. 15% parathion per 55 gals. of spray per acre.
[2] Apparent reduction from growth identical for both insecticides.
[3] Actual loss of insecticide deposit.
[4] Accidentally dusted with 5% DDT by the grower 13 days prior to harvest.

to determine the actual decrease of insecticide deposit as caused by weathering. The same analyses from which the actual residue in ppm were calculated, were recalculated on the basis of micrograms of insecticide per 5-plant sample, disregarding the sample weights. Within each series, these values are proportional to the residues in ppm which would remain on each analyzed sample if no growth occurred and the sample weight remained constant. The percentage loss calculated from these values, therefore, represents the actual loss of insecticide from the plants by all of the effects grouped under the term weathering, with the direct effects of growth eliminated.

Due to the many variable factors involved the percentages of actual insecticide losses, as shown under the weathering column of tables 1, 2 and 3, varied considerably, even for the same interval since the last application, but they did follow a trend. To show the actual loss trend during the last 2 weeks prior to harvest, weathering curves were plotted for each treatment by taking the mean of all the percentages of actual weathering loss as determined for samples taken approximately 7 to 14 days after the final application. These values appeared to be sufficiently independent of the stage of growth at which applications were made that all such loss figures could be pooled in determining the probable losses to be expected from a spray deposit applied 2 weeks before harvest. The weathering loss curves are represented for each material in figure 2 by the dot-dash lines.

Curves showing the reduction of residues due to the combined action of growth and weathering were plotted for the final 2 weeks before harvest and are represented by the solid lines in figure 2. The points for these curves were determined for the several intervals after application

Table 2.—The actual residue in ppm and micrograms per 5 lettuce plants at increasing intervals after 4 and 5 applications per plot of DDT or parathion wettable powder sprays; also the percentages of the apparent loss due to growth and the actual loss of insecticide deposit from weathering, 1950.[1]

Time in Days		Percentage Loss			Actual Residue			
		Weathering[3]			PPM		Micrograms per 5 Plants	
Before Harvest	Since Applic.	Growth[2]	DDT	Para.	DDT	Para.	DDT	Para.
				Four Applications				
Replicate 1								
25	0	0	0	0	58.7	2.2	8,223	335
18	7	83	48	40	5.88	0.32	4,304	201
17	8	84	70	42	3.49	0.28	2,485	196
12	14	90	78	100	0.84	0.0	1,844	0
0	25	97	68		0.66	0.0	2,628	0
				Five Applications				
17	0	0	0	0	105.	2.91	69,090	2,467
10	7	66	69	100	9.48	0.0	21,463	0
0	17	85	95		1.16	0.0	3,455	0
				Four Applications				
Replicate 2								
24	0	0	0	0	68.3	1.85	15,022	397
23	1	17	68	85	15.5	0.31	4,954	95
16	8	77	86	86	2.24	0.10	2,051	79
9	15	91	94	100	0.54	0.0	983	0
2	22	95	79		1.12	0.0	3,188	0
0	24	96	93		0.16	0.0	1,076	0
				Five Applications				
16	0	0	0	0	572.	1.06	345,528	678
9	7	58	59	100	7.97	0.0	143,787	0
2	14	79	90		10.3	0.0	34,429	0
0	16	80	93		6.86	0.0	25,156	0

[1] 2 lbs. 50% DDT and 0.5 lb. 15% parathion per 45 gals. of spray per acre.
[2] Apparent reduction from growth identical for both insecticides.
[3] Actual loss of insecticide deposit.

by multiplying the percentage of residue that remained after growth by the corresponding percentage of residue that was left after the weathering effect was deducted. All figures for these calculations were derived from the growth and weathering curves in figure 2 and the products thus obtained were used to establish the points for the curves that represented the total losses.

RESULTS.—The curves presented in figure 2 were prepared from the known and calculated DDT and parathion spray residue data, as given in tables 1 through 3, and the growth curve (Fig. 1). Figure 2 represents only the trend of the losses as caused by growth and weathering and is not intended to suggest that slight variations could not occur. The readings in the discussion to follow were taken from larger reproductions of the curves in order to better follow differences as noted under the conditions of these experiments.

DDT Wettable Powder Spray.—When reading from the graphs showing the total residue reduction note that only 5 per cent of the original residue, as determined immediately after the last application, would remain at harvest time if the final spray is applied 2 weeks prior to harvest. Growth, alone, during this period appeared to reduce the amount of residue in ppm by 73 per cent while weathering decreased the DDT deposit 80 per cent (Fig. 2).

DDT Oil Emulsion Sprays.—The curves for the dilute and concentrated DDT oil emulsion sprays were very similar. The difference was that weathering during the 2 weeks after application accounted for slightly more of the decrease of concentrated spray than of the dilute spray residue; also, the curves denoting the total loss indicated that the concentrated spray residue seemed to decrease a little more rapidly because of the increased weathering effect (Fig. 2); however, at the end of 14 days the two dilutions had approximately the same percentage of the original residue remaining. The difference in the

Table 3.—The actual residue in ppm and micrograms per 5 lettuce plants at increasing intervals after 4 and 5 applications per plot of DDT concentrated and dilute oil emulsion sprays; also the per cent of the apparent loss due to growth and the actual loss of insecticide deposit from weathering, 1950.[1]

Time in Days		Percentage Loss			Actual Residue			
		Weathering[3]			PPM		Micrograms per 5 Plants	
Before Harvest	Since Applic.	Growth[2]	Dilute	Conc.	Dilute	Conc.	Dilute	Conc.
				Four Applications				
Replicate 1								
27	0	0	0	0	81.5	71.1	7,010	5,840
20	7	83	79	74	5.28	4.38	1,511	1,499
13	14	94	56	39	2.62	2.99	3,089	3,586
6	21	97	92	47	0.13	0.83	556	3,145
0	27	98	43	—	0.96	3.06	4,009	11,979
				Five Applications				
20	0	0	0	0	34.1	31.8	12,207	11,138
13	7	62	33	67	6.22	3.32	8,149	3,662
6	14	84	83	76	0.66	0.71	2,135	2,669
0	20	89	53	61	1.46	1.16	5,794	4,374
				Four Applications				
Replicate 2								
33	0	0	0	0	79.9	63.0	4,793	5,989
32	1	0	7	40	51.0	42.7	4,489	3,590
28	5	44	64	91	12.49	5.88	1,723	529
21	12	88	84	97	1.6	0.57	670	178
13	20	97	74	94	0.81	0.34	1,241	356
0	33	99	100	99	0.0	0.02	0	85
				Five Applications				
28	0	0	0	0	150.	192.	9,892	16,490
21	7	83	71	86	8.31	8.55	2,908	2,308
13	15	95	88	93	1.44	1.68	1,153	1,176
0	28	98	85	100	0.06	0.0	1,503	0

[1] 1.5 qts. 25% DDT oil emulsion in 20 and 45 gals. of spray per acre.
[2] Apparent reduction from growth identical for both insecticides.
[3] Actual loss of insecticide deposit.

effect of weathering between the 2 dilutions is further pointed out in table 3.

When reading from the curves in figure 2 it was found that both dilutions had only 5 to 6 per cent of the original residue remaining 14 days after the final application. Growth accounted for a 73 per cent apparent reduction 2 weeks after the last application and weathering caused an actual loss of approximately 82 per cent of the concentrated spray and 78 per cent of the dilute spray deposit.

Parathion Wettable Powder Spray.—Fourteen days after the last application the apparent residue reduction from growth was 73 per cent, weathering caused an actual decrease of parathion spray deposit of more than 99 per cent, and less than 1 per cent of the original residue remained. These curves (Fig. 2) definitely point out that when parathion was applied at the low concentration of 0.075 pound per acre per application there was a rapid decrease of residue, reaching levels low enough to be within the range of analytical error in a relatively short time.

DISCUSSION.—It is evident from the given data that the combined action of growth and weathering for 2 weeks accounted for a reduction of 94 to 95 per cent of the DDT and 99 per cent of the parathion spray residues. Growth, alone, caused a 73 per cent apparent reduction of the insecticide residues during the final 2 weeks before harvest merely due to the increase of the weight of the plant, while weathering effected an actual loss of 78 to 82 per cent of the DDT and 99 per cent of the parathion original spray deposits.

The reduction of DDT and parathion residues on lettuce were shown to be very rapid due to the combined action of growth and weathering; however, these results are somewhat in agreement with the previous residue studies on other crops by various workers. DDT residue on

peaches was reported by Barnes *et al.* (1950) to decrease from an initial residue of 16.1 ppm to 2.7 ppm 30 days after application. Calculations show that this reduction represented an approximate 83 per cent loss. Borden (1947) applied 10 per cent DDT dust formulations, some of the dusts with added adhesives, to pears at the rate of 50 to 100 pounds per acre. From the results where no adhesives were used the data showed that there was an approximate 78 to 80 per cent reduction of DDT residue in 16 days and a 95 per cent decrease in 54 days. Brunson & Koblitsky (1950) reported that 70 per cent of the DDT wettable powder residue on peach leaves was lost during the week after the first application but very little more was lost during the second and third week. The same workers found DDT dust residues to decrease about 80 per cent in the first week after the initial application, with further loss during the second week. Eden & Arant (1948) reported the greatest decrease of DDT dust residues on alfalfa to occur within the first 10 days after application. Gunther *et al.* (1946) determined the loss of residue from each of 12 different treatments of DDT over a period of approximately 3 months and reported every treatment showed a loss of 71 to 95 per cent of the original deposit after 86 days. Analyses given by Poos *et al.* (1950) showed there was an approximate decrease of 95 per cent of the DDT residue on alfalfa during the interval between the eighth and thirty-fifth day after application. The loss was attributed to growth and weathering.

Parathion residue data on peaches by Barnes *et al.* (1950) from sprays containing 1 and 2 pounds of actual material showed a 95 to 100 per cent reduction of residue within 30 days. Ginsburg *et al.* (1950) found practically no parathion residue to be on crops harvested 12 days or more after the last application of 0.5 and 1 per cent dusts or from sprays containing 0.125 to 0.25 pound of actual parathion. Hoskins (1949) concluded that the parathion residue resulting from any practical spray schedule could be measured only in fractions of a part per million. Residues from applications of parathion sprays for red-banded leafroller control by King *et al.* (1948) that contained from 0.25 to 0.625 pound of actual insecticide showed decreases of 90 to 95 per cent of the initial deposit within 3 weeks. Mitchel *et al.* (1949) applied parathion in different formulations to apple trees at the rate of 1.2 to 1.5 ounces of actual parathion per tree. The data showed that there was a 56 to 98 per cent reduction in the parathion residue between the second and twenty-first day after treatment. Walker (1950) reported that parathion residues on apples, from applications of 0.25 to 1 pound of parathion as wettable powder sprays, decreased from 80 to 85 per cent in 12 to 13 days and 93 to 100 per cent in 30 to 32 days.

Most of the crops listed in the preceding discussion are considerably slower growing than is lettuce and in their case it would seem safe to assume that weathering was probably the most important factor in reducing the insecticide residue. There is a similarity in the results of the previous residue work with other crops and the actual loss of DDT and parathion deposits on lettuce by weathering alone. It is only when the dual effect of growth and weathering is considered that the difference in the speed of residue loss is clearly shown between a fast growing crop, such as lettuce, and those that grow more slowly.

The results of the residue study on lettuce show the following important facts: 1) Growth was reproducible for the marketable heads, and the effect of this factor alone, in many cases, would result in safe levels of DDT or parathion residues at harvest time. 2) The weathering of DDT or parathion spray deposit was found to be more consistent in the different years than was expected. 3) The original spray deposits were variable but within the range giving safe levels of residue at harvest after the effects of growth and weathering had taken place for a 2-week period.

Through this study the prediction that safe DDT and parathion residues can be depended upon in the future is much more certain than would be the case when relying on harvest analyses alone, and the reduction due to growth can be applied to any insecticide that might be used on Iceberg lettuce in the future.

SUMMARY.—A study of the DDT and parathion residue problem on Iceberg lettuce in New York afforded an opportunity to determine the importance of growth and weathering on the apparent and actual loss of these insecticides. Residue samples were taken from six-spotted leaf-

hopper control plots that received four to six applications of DDT or parathion wettable powder and two dilutions of DDT oil emulsion sprays.

To determine the effect of growth on the apparent reduction of residue (decrease in ppm) a growth curve was plotted for Iceberg lettuce. By utilizing this curve, and the residue analyses of lettuce samples in ppm and micrograms of insecticide deposit per 5-plants, as taken at various intervals until harvest from the DDT and parathion spray plots, calculations were made to determine separately the percentage of residue reduction that was caused by growth or weathering. The resulting values were then plotted as curves for each insecticide or formulation to show the importance of growth during the final 2 weeks prior to harvest in the apparent reduction of residue, the actual loss of insecticide deposit as caused only by weathering, and the per cent of the original residue that would be lost due to the combined action of growth and weathering at a given date after application.

All DDT or parathion spray residues on Iceberg lettuce were shown to decrease some 94 to 99 per cent within 14 days when the last application was made 2 weeks prior to harvest. Growth, alone, accounted for an approximate 73 per cent apparent decrease of residue while the percentage of actual insecticide spray deposit loss, as caused by weathering over the 14 day period, approximated 80 to 99 per cent of the original deposit for the DDT and parathion sprays respectively.

LITERATURE CITED

Arant, F. S. 1948. Status of velvetbean caterpillar control in Alabama. JOUR. ECON. ENT. **41**(1): 26–30.

Barnes, M. M., G. E. Carman, W. H. Ewart and F. A. Gunther. 1950. Fruit surface residues of DDT and parathion at harvest. Advn. Chem. Ser. **1**: 112–6.

Borden, A. D. 1947. DDT dust deposits on pears. JOUR. ECON. ENT. **40**(6): 926–7.

Brunson, M. H., and Louis Koblitsky. 1950. A study of DDT deposits on peach foliage and fruit treated for control of the oriental fruit moth. U.S.D.A.—B.E.P.Q. **E-809.**

Burgess, A. F., and Harvey L. Sweetman. 1949. The residual property of DDT as influenced by temperature and moisture. JOUR. ECON. ENT. **42**(3): 420–3.

Chisholm, R. D., and Louis Koblitsky. 1947. Effect of light on DDT residues. Agr. Chem. **2**(9): 35–7.

Dustan, G. G., T. Armstrong and W. L. Putman. 1947. The influence of air currents on the insecticidal action of DDT, BHC, Hericules toxicant 3945, and Velsicol 1068. Can. Ent. **79**(1): 45–50.

Eden, W. G., and F. S. Arant. 1948. DDT residues on alfalfa. JOUR. ECON. ENT. **41**(3): 383–7.

Fahey, Jack E., and Harold W. Rusk. 1939. A field method for the chemical evaluation of spray deposits resulting from the application of insecticides for control of the codling moth. U.S.D.A.—B.E.P.Q. **E-491.**

Fleck, E. E. 1944. Rate of evaporation of DDT. JOUR. ECON. ENT. **37**(6): 853.

Fleck, E. E. 1949. The action of ultra-violet light on DDT. Amer. Chem. Soc. Jour. **71**(3): 1034–6.

Gahan, J. B., B. V. Travis and A. W. Lindquist. 1945. DDT as a residual-type spray to control disease-carrying mosquitoes: Laboratory tests. JOUR. ECON. ENT. **38**(2): 236–40.

Ginsburg, J. M., R. S. Filmer and J. P. Reed. 1950. Longevity of parathion, DDT and dichlorodiphenyl dichloroethane residues on field and vegetable crops. JOUR. ECON. ENT. **43**(1): 90–4.

Goddin, A. H., and M. C. Swingle. 1945. Experiments with DDT conducted by E. I. du Pont de Nemours and Co., Inc. U.S.D.A.—B.E.P.Q. **E-644d.**

Gunther, F. A. 1945. Aspects of the chemistry of DDT. Jour. Chem. Ed. **22**: 238–42.

Gunther, F. A., D. L. Lindgren, M. I. Elliot and J. P. LaDue. 1946. Persistence of certain DDT deposits under field conditions. JOUR. ECON. ENT. **39**(5): 624–7.

Gunther, F. A., G. E. Carman and M. I. Elliot. 1948. Inhibition of the field decomposition of DDT spray deposits on citrus; preliminary results. JOUR. ECON. ENT. **41**(6): 895–900.

Hamilton, Clyde C. 1929. The growth of the foliage and fruit of the apple in relation to the maintenance of a spray coating. JOUR. ECON. ENT. **22**(2): 387–96.

Hoskins, W. M. 1949. Deposit and residue of recent insecticides resulting from various control practices in California. JOUR. ECON. ENT. **42**(6): 966–73.

King, H. L., R. Hutson and T. H. Farr. 1948. The control of red-banded leaf roller with parathion. JOUR. ECON. ENT. **41**(6): 976–7.

Lindquist, A. W., H. A. Jones and A. H. Madden. 1946. DDT residual-type sprays as affected by light. JOUR. ECON. ENT. **39**(1): 55–9.

Mitchel, A. E., H. King, E. K. Carr and E. J. Benne. 1949. The relation between different methods of applying parathion and the amounts deposited on apple leaves for the control of European red mite. Mich. Agr. Exp. Sta. Quart. Bul. **31**(3): 309.

Poos, F. W., T. N. Dobbins and R. H. Carter. 1950. Sampling forage crops treated with organic insecticides for determination of residues. U.S.D.A.—B.E.P.Q. **E-793.**

Stanley, W. W. 1945. Leaf area and its relation to application of insecticides. JOUR. ECON. ENT. **38**(6): 703–5.

Sweetman, Harvey L. 1945. The residual toxicity of DDT. Influence of temperature and moisture on the residual kill of DDT. Soap and Sanitary Chem. **21**(12): 141, 143, 145, 147, 149, 171.

Walker, K. C. 1950. Parathion spray residue on soft fruits, apples, and pears. Advn. Chem. Ser. **1**: 123–7.

Webster, R. L. 1950. New insecticides: their use, limitations and hazard to human health. Wash. Agr. Expt. Sta. Circ. **64**.

Wichmann, H. J., W. I. Patterson, P. A. Clifford, A. K. Klein and H. V. Claborn. 1946. Decomposition and volatility of DDT and some of its derivatives. Jour. Assoc. Off. Agr. Chem. **29**: 218–33

DDT and Parathion for San Jose Scale Control[1]

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DDT became generally available to fruit growers in 1945. Superior codling moth control with DDT quickly led to its general acceptance for this purpose, displacing the lead arsenate or cryolite formerly used.

Prior to the general adoption of DDT for codling moth control, San Jose scale was a serious economic orchard pest. Annual applications of dormant or delayed dormant sprays of oil, lime sulfur, or mixtures of oil-lime sulphur were necessary if serious losses were to be prevented. Washington orchards are generally dependent on irrigation water for spray purposes and water is not usually available for dormant spraying, thus forcing many growers to use a delayed dormant spray. Moreover, delayed dormant sprays occasionally cause severe injury to the trees. This situation has inclined growers to omit the dormant sprays altogether or defer their application until the necessity for control became apparent.

Careful observations made at the Tree Fruit Experiment Station and in grower orchards, where dormant sprays have been omitted, indicate:

(1) Orchards receiving two or more DDT cover sprays have not had an increase in scale infestation, despite the omission of dormant sprays during the past 3 to 5 years.

(2) Orchards not receiving DDT or other materials effective for scale control in the cover sprays have had a significant increase in scale infestation when the dormant sprays were omitted.

(3) Cherry or other stone fruit orchards which generally do not receive cover sprays of DDT have experienced serious scale infestations when the dormant sprays were omitted.

An opportunity was afforded, in the spring of 1948, to conduct experiments for the control of San Jose scale in an Italian prune orchard near Cashmere, Washington. The grower stated he found it impossible to control San Jose scale in this orchard with two annual dormant lime sulfur sprays. The trees were severely infested, with many limbs and branches dead from encrusted scale. A section of the orchard with the most severe infestation was used for the tests. Single rows of 5 trees each were used for single plot treatments. Table 1 shows the materials, concentration, time of application and stage of bud development.

Table 1.—Materials in 100 spray gallons and application dates. Cashmere, Wash. 1948.

Plot 1	Parathion	1 lb.[1]	April 21 (green tip stage of bud development)
Plot 2	Parathion	1 lb.	June 4 (first cover spray)
Plot 3	Parathion	2 lbs.	June 14[2]
Plot 4	Parathion	1 lb.	June 15 (do.)
Plot 5	DDT[3]	2 lbs.	June 15 (do.)
Plot 6	Check, Untreated		

[1] 25 per cent wettable powder, American Cyanamid Company.
[2] Timed to precede appearance of crawlers. First noted June 18.
[3] 50 per cent wettable powder, Penn. Salt Manufacturing Company.

A satisfactory method for the critical evaluation of San Jose scale control presents many difficulties. Counts of dead and living scale on twigs is a laborious and time consuming job, since several thousand scale may infest a single branch or twig only a few inches in length. A count of the scale-infested fruits at harvest does not necessarily show the ef-

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Table 2.—San Jose scale counts on twigs, June 26, 1948.

Plot No.	No. Scales		No. Crawlers	
	Alive	Dead	Alive	Dead
1	1	99	0	0
2	22	78	0	0
3	38	62	0	0
4	30	70	0	0
5	57	43	57	61
6	98	2	686	0

ficiency of control measures, since the tree wood may be infested while the fruit is not.

On June 26, ten encrusted twigs were taken from each plot and examined by binocular microscope to determine scale mortality and the presence of scale crawlers. These data are shown in Table 2.

Table 3.—Total scales and crawlers.

Plot No.	Settled Scale	Crawlers
1	195	5
2	157	3
3	42	0
4	39	4
5	164	15
6	2473	139

In mid-July, a second sample of wood was taken from all plots for examination. Ten twigs per plot were used. The twigs were taken as current season's terminal growth of approximately 6 inches in length. Examination of this new growth, together with 5 leaves per twig for settled scales or crawlers, should afford a reliable comparison of the control. These data are shown in summary in table 3.

The fruit was harvested September 30 and October 2, at which time the fruit was examined for scale and recorded as shown in Table 4.

The owner of the orchard expressed some concern because of the severe scale infestation present on the check plot and made a request that it be reduced if possible. In consequence, a spray of 1 lb. 25 per cent parathion wettable powder per 100 gallons of spray was applied to the entire series of plots in late October. A final sample of 10 twigs per plot was collected on March 8, 1949. All scale present on the wood grown in 1948 was carefully examined to determine scale mortality. The characteristic scale marks on the twigs were also recorded, since numerous scales killed by the fall insecticide treatment would slough off during the winter. A sample taken from the orchard not included in the experimental area was included in the samples as plot 7. Table 5 summarizes the number of living and dead

Table 5.—San Jose scale infested twigs, March 3, 1949.

Plot No.	Live Scales	Dead Scales	Scale Marks
1	1	7	4
2	0	8	5
3	0	12	6
4	0	1	4
5	7	34	93
6	31	135	122
7	178	124	42

Table 4.—Scale infested prune fruits at harvest.

	Plot No.	Scale Free	1 Scale	2–5 Scales	6+ Scales
Number of Fruits	1	2297	135	56	17
Per Cent Infested		91.7%	5.3%	2.2%	0.6%
Number of Fruits	2	1632	279	341	239
Per Cent Infested		65.5%	11.2%	13.7%	9.6%
Number of Fruits	3	2434	50	18	0
Per Cent Infested		97.3%	2%	0.3%	0
Number of Fruits	4	2428	57	33	15
Per Cent Infested		95.8%	2.2%	1.3%	0.5%
Number of Fruits	5	1886	322	254	87
Per Cent Infested		74%	12.6%	10%	3.4%
Number of Fruits	6	992	398	649	512
Per Cent Infested		38.8%	15.6%	25.4%	20%

scales and the number of scale marks for the respective samples.

SUMMARY.—Insecticide treatments were made on Italian prunes at Cashmere, Washington, in 1948 for the control of San Jose scale. DDT was used at 2 lbs. 50 per cent wettable powder per 100 gallons of spray and applied just prior to the appearance of crawlers. Parathion was used at various intervals at 1 or 2 lbs. of the 25 per cent wettable powder. Results indicate DDT is very effective for the control of crawlers. However, it is slow acting and fruit marking may occur before mortality results. Parathion kills a high percentage of gravid females, reducing the number of crawlers. Either material should control San Jose scale when properly timed. A combination of the materials is suggested to prevent fruit marking under conditions of severe infestation.

Field Tests with Ethylene Chlorobromide on Wireworms

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Preliminary field tests were conducted during the 1950 season in Ventura County, California, to determine the value of ethylene chlorobromide as a fumigant for the control of the sugar-beet wireworm, *Limonius californicus* Mann.

In the initial test ethylene chlorobromide was compared with ethylene dibromide[1] in controlling wireworms feeding on the roots and in the stems of lima bean plants. The fumigants were applied with an 8-blade soil-fumigant applicator of the continuous-flow type. The injection blades were set to deliver the fumigants 7 inches deep on both sides of the row at a distance of 6 inches from the plants. Each material was applied to 15,600 feet of row, at the rate of 8.5 gallons of solution per acre. The lima beans (Ventura variety) were planted on May 5, and the treatments were applied on May 19. Four days after treatment 16 soil samples (each 4 by 4 inches by 3 feet) were taken at random in the bean rows, and each was sifted to recover the wireworms present. Of the wireworm larvae recovered, 85 per cent in the rows treated with ethylene chlorobromide and 96 per cent in those treated with ethylene dibromide were dead. No further wireworm damage to the plants occurred, and there was no indication that the plants had been adversely affected by the fumigation.

With a plentiful supply of wireworms, it was possible to obtain data on the range of diffusion of these fumigants in the soil. At distances of 6, 9, and 12 inches from the point of injection holes 1 inch in diameter were bored with a soil auger to a depth of 12 inches. For each test 2 milliliters of one of the solutions was injected

[1] Eston Chemicals, Inc., furnished these materials. They were dissolved in a volatile organic solvent. Each gallon of the ethylene dibromide and ethylene chlorobromide solution contained 3.6 pounds, or 40 and 42 per cent, respectively, by weight, of the technical-grade material. The ethylene dibromide solution weighs 8.9 pounds and the ethylene chlorobromide solution 8.6 pounds per gallon. Physical properties of ethylene chlorobromide furnished by manufacturer: molecular weight 143.4; density 1.7 to 1.73 grams per milliliter; boiling point 107° C.

Table 1.—Mortality of wireworms in cages placed at different distances and depths from point of injection of 2-milliliter doses of ethylene dibromide and ethylene chlorobromide solutions.

Fumigant	Wireworms Used	Inches from Point of Injection	Per Cent Mortality of Wireworms in Cages at Indicated Depths in Inches			
			0–4	4–8	8–12	All depths
None	447	—	6.0	8.7	7.4	7.4
Ethylene dibromide	438	6	89.2	97.8	49.3	78.8
		9	42.6	22.2	18.5	27.7
		12	5.8	0	5.5	3.4
Ethylene chlorobromide	433	6	82.4	82.4	15.8	59.8
		9	16.3	7.8	5.3	9.8
		12	2.8	3.2	0	2.0

Table 2.—Comparative effectiveness of ethylene chlorobromide and ethylene dibromide solutions when tested against wireworms in a field of lima beans, G. Chaffee field, Saticoy, California.

Fumigant	Gallons per Acre	Wireworms per Foot of Bean Row		Per Cent Mortality of Wireworms Caged for 7 Days at Different Depths					Plants per Foot of Bean Row		Pounds of Dry Lima Beans per 0.01 Acre
		Before Treatment	After Treatment	0–4	4–8	8–12	12–16	Average at All Depths	June 5	Aug. 4	
				Inches							
None	0	2.4	0.8	0	2	0	2	1	1.3	1.1	21.0
Ethylene chlorobromide	11	1.6	0.13	83	62	46	7	51	1.6	1.4	22.3
Ethylene chlorobromide	22	1.8	0.04	98	100	94	69	90	1.5	1.3	25.4
Ethylene dibromide	11	2.0	0.03	94	87	71	40	70	1.5	1.4	24.3
Difference required for significance (odds 19:1)		[1]	0.25	—	—	—	—	—	0.13	0.12	2.4

[1] Not significant according to the *F* test.

into the soil to a depth of 4 inches. Three screen cages (1 by 4 inches), each containing moist soil, wheat, and five medium-size *Limonicus californicus* larvae, were inserted, one above the other, in each hole. These tests were conducted in Yolo sandy loam soil which had a moisture content ranging from 12 per cent at the 0–4 inch depth to 14 per cent at the 8 to 12 inch depth. The soil was in excellent condition for planting, having been plowed a month previously. Each material and check was tested five times on two occasions, during a period when soil temperatures at 6 inches depth ranged from 57° to 77° and averaged 65.9° F.

After 8 days' exposure the cages were removed and the living larvae placed in salve cans for examination 10 days later. The mortality obtained in these tests (Table 1) showed conclusively that the ethylene dibromide solution was more toxic to the wireworms at all positions than equal dosages of the ethylene chlorobromide solution. Nevertheless, ethylene chlorobromide showed some promise and appeared worthy of further trial under field conditions.

A field experiment was then inaugurated on the Chaffee farm to compare the effectiveness of ethylene chlorobromide solution when applied at the rates of 11 and 22 gallons and ethylene dibromide solution at 11 gallons per acre. The plots were 40 by 200 feet, and each treatment and check was replicated six times in a randomized-block layout. The 4.4-acre area used for this test had been planted in the early spring to seed zinnias, which were disked under because of a thin stand due to damage by wireworms. As a check on the wireworm population of the plots before treatment, a row of lima beans was planted through each block on May 1. Seven days later six soil samples (4 by 4 inches by 3 feet) were taken at random in the bean row of each plot, and each was sifted through a 12-mesh screen to recover the wireworms present. The reduction in wireworm population was determined by taking a similar number of samples 6 days after the main crop of limas was planted on May 24. The plots were treated on May 10 with an 8-blade fumigant applicator of the tractor-driven, pull type. The materials were applied 7 inches deep at 12-inch spacings. A heavy rake attached to the rear of the applicator served to seal the openings made by the injector blades. The soil was Yolo sandy loam with a moisture content ranging from 13.7 per cent, by weight, at the 4-inch depth to 18.2 per cent at the 16-inch depth. Soil temperatures on the day of treating reached a maximum of 70° F. at 4 inches and 66° at the 8- and 12-inch depths.

To determine the wireworm mortality at various soil depths, two holes were bored in each plot with a soil auger 1 inch in diameter to a depth of 16 inches immediately after treatment. Four screen cages (1 by 4 inches), each containing 5 medium-size *Limonius californicus* larvae, were inserted, one above the other, in each hole. Owing to the grower's desire to plant as soon as possible, the cages were removed from the soil after 7 days. Before the beans emerged a 0.01-acre area (4 rows 43.5 feet long) was staked out in the center of each plot. Stand and yield data were obtained by counting the plants and harvesting the dry lima beans from this area.

As judged by the wireworm mortality obtained in cages (Table 2), the low dosage of ethylene chlorobromide did not

give adequate control of wireworms, especially at the lower depths, whereas the higher dosage gave exceptionally good kill at all depths. However, it is possible that the mortality of the caged wireworms in these plots, and those treated with the ethylene dibromide as well, would have been higher had the cages remained in the soil longer. The wireworm population of the bean rows in all treated plots was significantly lower than in the untreated, which indicates that most of the wireworms were near the surface in the range of the fumes at the time of treating. Plant counts made in early June and in August showed that wireworms had been responsible for the destruction of more than 18 per cent of the seed or plants in the untreated plots and that some damage to the plants had occurred in these, as well as in the treated plots, during the summer. The lower dosage of the ethylene chlorobromide did not increase the yield of lima beans, but the higher dosage and the ethylene dibromide treatment gave significant increases in yield, which would more than compensate for the cost of materials and their application.

The Toxicity of Cumulative Spray Residues in Soil

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The problem of the cumulative effect of spray materials through soil toxicity from the ever increasing amounts of new and highly toxic spray materials being applied in commercial orchards in the Cumberland-Shenandoah fruit belt of West Virginia is of major concern since it affects the trees directly and indirectly through its effects on cover crop, nutrient condition and soil fauna and flora.

In the spring of 1948 preliminary studies were begun to determine the effect of various insecticides, fungicides and other materials on plant and animal life when applied directly to the soil. While the results obtained to date have been striking and very significant, yet they are considered preliminary and should not be over-emphasized until they have been verified. In view of the wide publicity given these results, it seems desirable to present them for clarification.

The experiment was designed to simulate commercial orchard conditions as nearly as possible with available facilities. The plot design consisted of an area of 10 by 20 feet with one apple and one peach tree in each plot, thus giving 100 square feet per tree or 200 square feet per plot. The randomized plots were replicated five times in each block. The experimental area was divided into three blocks designed for testing 10 different materials or treatments at three concentration levels, each concentration being confined within the block. The materials tested were DDT, parathion, zinc-lime, benzene hexachloride, arsenate of lead, sulphur, fermate, chlordane, toxaphene and 2-4-D. Commercial spray recommendations served as a basis for determining the concentrations tested. The three concentrations tested included normal, 10 times (X-10) normal and 30 times (X-30) normal. The normal concentration was based on the use of 1000 gallons of spray per acre per application which was considered somewhat greater than average heavy commercial spraying. Four or five applications were made depending on the materials being used. The amounts of materials used are given in table 1. The applications were timed to coincide with timing of the recommended commercial spray schedule. All materials were applied directly to the ground in a water suspension or solution except where the amount of material was too great in which case the dry material was applied directly to the ground and the water applied on top of the material. All treatments were repeated again in the spring of 1949; however, the results reported are considered to be due mainly to the 1948 treatments. The trees used in this experiment were one year old 7 to 9 sixteenths caliper standard nursery stock which were headed back to 36 inches at time of

[1] Authorized for publication as Scientific Paper No. 441 by the director of the West Virginia Agricultural Experiment Station.

Table 1.—Amounts of materials[1] used—1948.

Plot No.	Materials	Area	Normal Concentration		Yearly Dosage at Conc. of:	
			Application	Year	X-10	X-30
1	Check	—	—	—	—	—
2	DDT—50%	Plot	1.48 oz.	6.0 oz.	60 oz.	180 oz.
		Acre	20 lbs.	80 lbs.	800 lbs.	2400 lbs.
3	Parathion 25%	Plot	0.4 oz.	1.5 oz.	15 oz.	45 oz.
		Acre	5.0 lbs.	20 lbs.	200 lbs.	600 lbs.
4	ZnSO4+	Plot	4.5 oz.	18 oz.	180 oz.	540 oz.
		Acre	60 lbs.	240 lbs.	2400 lbs.	7200 lbs.
	Lime	Plot	6 oz.	24 oz.	240 oz.	720 oz.
		Acre	80 lbs.	320 lbs.	3200 lbs.	9600 lbs.
5	Benzene Hexachloride	Plot	1.5 oz.	6.0 oz.	60 oz.	180 oz.
		Acre	20 lbs.	80 lbs.	800 lbs.	2400 lbs.
6	Arsenate of lead	Plot	2.0 oz.	8.0 oz.	80 oz.	240 oz.
		Acre	30 lbs.	120 lbs.	1200 lbs.	3600 lbs.
7	Micronized Sulphur	Plot	4.5 oz.	22 oz.	220 oz.	660 oz.
		Acre	50 lbs.	250 lbs.	2500 lbs.	7500 lbs.
8	Fungicide[2]	Plot	1.1 oz.	4.4 oz.	44 oz.	132 oz.
		Acre	15 lbs.	75 lbs.	750 lbs.	2250 lbs.
9	Chlordane 40%	Plot	1.8 oz.	7.4 oz.	74 oz.	221 oz.
		Acre	25 lbs.	100 lbs.	1000 lbs.	3000 lbs.
10	Toxaphene 40%	Plot	Out	Out	74 oz.	Out
		Acre	Out	Out	1000 lbs.	Out
11	2-4-D	Plot	Out	Out	0.18 gr.	Out
		Acre	Out	Out	400 gr.	Out

Normal: This concentration was based on the use of 1000 gallons of spray per acre per application; the number of applications was four or five depending on the material being used.
X-10: Concentration was 10 times the amount of normal or the amount which would normally be applied in 10 years by following the recommended spray schedule.
X-30: Concentration was 30 times the normal or the amount which would be applied in 30 years.
[1] All materials were commercial formulations available for general commercial use.
[2] *Fermate.*

setting. Some of the peach trees produced fruit in 1950, but not enough to determine the effect of treatments on fruiting. There were sufficient fruits on some plots including the benzene hexachloride, to permit flavor tests; however, these results have not yet been determined.

The standard rye-barley-vetch-crimson clover peach cover crop program was followed. The cover crops were seeded in early September and trash-disced in the spring about time the rye was in the tough dough stage.

The potential value of the results from this experiment cannot yet be fully determined. The most significant results clearly apparent to date are the increased tree vigor, elimination of the cover crop and the control of woolly aphis on the roots of established apple trees. The most striking results were recorded for the benzene hexachloride plots. The first indications of phytotoxicity were noted on the rye cover crop in the benzene hexachloride plots. This was in the form of definite chlorosis and stunting which gradually grew worse until the cover crop was disced down. After the rye was disced down a heavy volunteer weed cover crop developed in all of the plots except the benzene hexachloride and X-10 and X-30 sulphur plots. There was complete elimination of all cover crop in the X-10 and X-30 benzene hexachloride and sulphur plots and marked phytotoxicity in the normal benzene hexachloride and X-30 chlordane plots. There was marked early phytotoxicity in the chlordane plots but they later recovered and produced a very luxuriant growth of foxtail and crab grasses.

The cover crop yield records for 1949 and 1950 are summarized in table 2, along with the soil organic content determinations. These results show clearly the toxic effect on cover crops of such materials as benzene hexachloride, sulphur and chlordane. The higher concentrations of arsenate of lead and zinc-lime also showed marked toxicity to the cover crop. Neither parathion nor fermate showed any apparent toxic effect on the cover crop. The normal concentrations of standard materials such as arsenate of

Table 2.—Cover crop yield records and soil organic content.[1]

Plot No.	Materials	Concentrations	Green Weight in Tons per Acre				Per Cent Organic Content Jan. 1950
			1949		1950		
			May 5	Sept. 1	June 5	Sept. 11	
1	Check	—	12.0	16.3	7.1	6.8	2.7
2	DDT	Normal	12.0	19.7	7.1	10.5	2.7
		X-10	8.6	12.3	5.2	7.1	2.3
		X-30	6.2	11.7	3.4	5.0	2.2
3	Parathion	Normal	8.3	18.5	5.5	9.5	2.5
		X-10	13.6	15.0	8.2	9.2	2.3
		X-30	15.1	16.3	7.7	7.4	2.4
4	Zinc-Lime	Normal	11.4	15.1	6.8	8.3	2.9
		X-10	12.3	9.2	5.9	4.3	2.4
		X-30	9.9	7.7	3.1	2.5	2.2
5	Benzene Hexachloride	Normal	10.5	9.2	3.4	3.4	2.7
		X-10	—	—	—	—	2.3
		X-30	—	—	—	—	1.6
6	Arsenate of Lead	Normal	13.6	18.5	8.9	8.6	2.7
		X-10	11.1	10.8	5.8	4.3	2.4
		X-30	5.2	11.1	4.0	3.7	1.3
7	Sulphur	Normal	7.7	14.5	5.2	7.7	2.8
		X-10	—	—	—	3.1	2.1
		X-30	—	—	—	—	2.3
8	Fungicide	Normal	11.4	16.6	7.1	10.2	3.0
		X-10	15.4	12.6	7.7	8.9	3.0
		X-30	11.1	14.8	5.9	7.1	2.5
9	Chlordane	Normal	9.9	18.5	7.7	10.5	2.7
		X-10	12.0	13.3	2.5	4.3	2.5
		X-30	5.9	12.0	.6	.3	2.2
10	Toxaphene	X-10	7.7	10.8	4.0	2.8	2.4
11	2-4-D	X-10	12.6	14.8	5.2	4.9	2.2

[1] The organic determinations were made by the modified Walker and Black method.

lead, DDT, zinc-lime and chlordane did not show significant phytotoxicity to the cover crops but the higher concentrations of all of them did, particularly the X-10 treatment of toxaphene. There was a fairly close correlation between the amount of cover crop and the soil organic content.

The first apparent value of the benzene hexachloride treatments for general commercial use was that of weed control to reduce or eliminate the necessity of cultivation in young orchards thus reducing production costs. It was soon apparent, however, that more significant and important results were in increased tree vigor. Some of the more striking tree growth records are summarized in table 3.

By the end of the first growing season the peach trees in the X-10 benzene hexachloride plots showed a total terminal growth of 4.4 times that of the check trees. The trees in the normal and X-30 benzene hexachloride plots also showed significant increase in tree vigor over those of the check plots but not equal to that of the trees in the X-10 plots. The trees in the X-10 and X-30 sulphur plots also showed significant increase in tree vigor but not equal to those in the X-10 benzene hexachloride plots. The peach trees in the X-10 and X-30 arsenate of lead plots were the only ones which indicated definite toxicity. It was not possible to tabulate complete growth records for the peach trees for the second season but those which were obtained showed even greater differences than those for the first growing season. The apple trees in all of the benzene hexachloride plots and in the X-10 and X-30 chlordane plots showed significant increased vigor over those of the check plots.

The apple trees were removed at the end of the second growing season to permit study of the root systems and to obtain complete growth records. The trees were removed by means of a hydraulic lift in order to recover as much of the root systems as possible. Complete growth records of the trees together with descriptive notations on the condition of the root systems were recorded. Each root system was rated according to con-

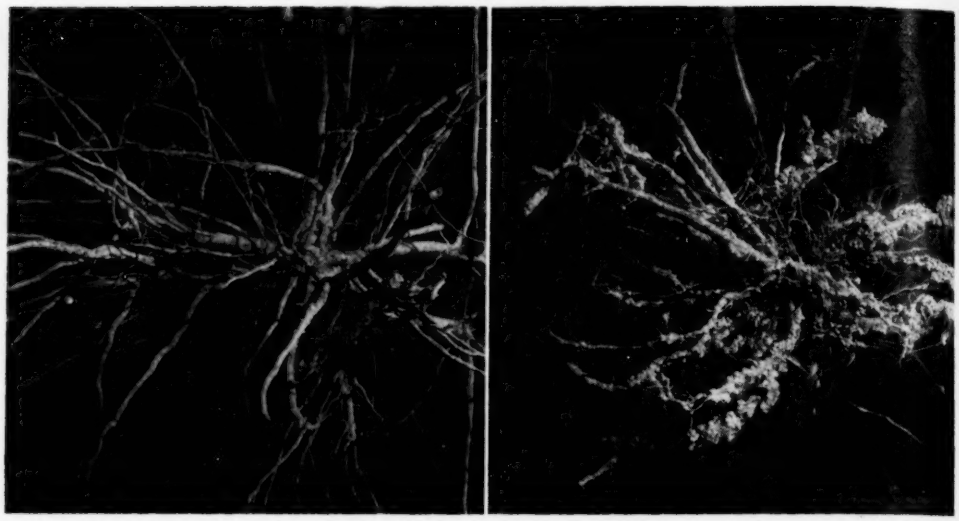

FIG. 1.—(Left) Roots of apple trees when benzene hexachloride was added to the soil. (Right) Woolly aphid galls on roots of apple trees in untreated soils.

dition and degree of infestation by woolly apple aphid *Eriosoma lanigerum* (Haus.) but no satisfactory method was apparent to accurately record the exact degree of infestation. Infestation was unusually severe affording conditions favorable for showing striking differences in relative effectiveness of the various treatments and also the exact degree of control.

The results on woolly aphid control with the various treatments were even more striking than their effect on tree growth. The results were sharp and clear cut. They were very significant in that there was an unusually heavy infestation of woolly aphid throughout the entire area. All three concentrations of benzene hexachloride and the X-30 concentrations of parathion and chlordane gave complete control of woolly aphids on the roots of established apple trees. All other plots showed at least one tree infested with aphids thus adding to the significance of the results. The X-10 chlordane plots showed only one tree with a very light infestation indicating that this concentration may have been near the minimum which is effective.

The reasons for the increase in tree vigor of both apple and peach trees are not clearly apparent but they are thought to be due to a number of factors. The complete absence of a cover crop in the benzene hexachloride and sulphur plots

Table 3.—Average lineal growth of apple trees for 1948 and 1949 and for peach trees for 1948—(Measurements in inches).

Plot No.	Materials	Concentration					
		Normal		X-10		X-30	
		Apple	Peach	Apple	Peach	Apple	Peach
1	Check	1028.2	327.9	—	—	—	—
2	DDT	776.3	283.7	807.8	390.8	1296.7	304.1
3	Parathion	1011.4	228.0	1158.1	315.9	1357.2	379.7
4	Zinc-Lime	811.4	215.3	698.0	291.8	957.5	397.8
5	Benzene Hexachloride	1679.0	615.3	1785.6	1438.2	1600.1	1021.9
6	Arsenate of Lead	899.3	265.6	918.6	176.0	963.6	133.5
7	Sulphur	876.6	290.2	1433.3	700.6	909.7	1200.0
8	Fungicide	1014.5	352.7	735.2	294.9	799.4	231.2
9	Chlordane	979.7	230.6	1388.3	416.4	1704.0	292.7
10	Toxaphene	—	—	1051.1	323.1	—	—
11	2-4-D	—	—	1002.9	259.1	—	—

Table 4.—Soil fauna populations.

Plot No.	Materials	Concentrations		
		Normal	X-10	X-30
1	Check	1100	—	—
2	DDT	778	121	25
3	Parathion	4403	752	100
4	Zinc-lime	4027	2295	3062
5	BHC	156	8	3
6	Ars. of Lead	4171	499	346
7	Sulphur	1357	210	53
8	Fungicide	3395	553	299
9	Chlordane	37	5	4
10	Toxaphene	—	28	—
11	2-4-D	—	4460	—

was certainly a contributing factor by reducing plant competition. In the sulphur plots, however, there was little apparent effect on the vigor of the apple trees thus somewhat discounting the importance of competition. Moreover, the peach trees in the X-10 benzene hexachloride plots were more vigorous than those in the X-30 concentration indicating either toxicity or the influence of other factors than plant competition. Other factors considered are more involved and include organic and nutrient balance in the soil, ionic relationship, changes in microorganism populations, relative nutritive value of the plant tissues and control of injurious pests such as woolly aphids and nematodes. The control of woolly aphis is of special significance since so far as is known this is the first report of effective and practical control for this pest on the roots of established apple trees.

After the apple trees were removed in the spring of 1950 new nursery stock was reset in the same locations to determine reestablishment. To date all trees have survived except those in the X-10 and X-30 benzene hexachloride and sulphur plots. There was mortality of all trees in these plots.

Soil Arthropod[1] population determinations were made by the Berlese funnel method. The determinations were made on four soil samples taken from each plot or 20 samples per treatment. Each sample consisted of a core of soil 4 inches in diameter and 6 inches deep. The recovered soil forms consisted mainly of Collembolids of the sub-order Arthropleona. The results given in table 4 represent the total population of all samples from the five replicate plots. Determinations were made in January 1950.

The results indicated that all concentrations of benzene hexachloride and chlordane were extremely toxic, reducing arthropod populations to a very low level in all plots. The DDT showed extreme toxicity in the X-10 and X-30 plots but only slight toxicity in the normal plots. Parathion showed severe toxicity in the X-30 plots, some toxicity in the X-10 plots but showed an increase in arthropod populations in the normal plots. All zinc-lime plots showed a very significant increase in arthropod populations. This was the only treatment which showed increased populations in the X-10 and X-30 blocks. The normal concentrations of fermate, parathion and arsenate of lead and the 2-4-D treatments also showed a significant increase in arthropod populations. The relation of arthropod populations and soil organic content was not consistent but indicated that the soil populations were affected more by the chemical treatments than by the organic content of the soil.

Widespread interest in the experiment resulted in the commercial treatment of an estimated 100,000 young apple, peach and cherry trees throughout the Cumberland-Shenandoah fruit belt during 1949 and 1950. Since best results were obtained with X-10 concentration of benzene hexachloride it was the one used as a basis for the commercial testing. This concentration is equivalent to approximately 0.3 ounce of 10 per cent benzene hexachloride per square foot of surface. For practical application it was suggested that the treatment be applied to an area of about 10 square feet per tree or to that area normally worked in hand cultivation. For economy and convenience it was suggested that the benzene hexachloride be made into a stock solution in the spray tank at the rate of 20 pounds of 10 per cent benzene hexachloride per 100 gallons and applied at the rate of one gallon of stock solution per tree or per 10 square feet. It is still too soon to evaluate the results of these extensive tests.

[1] Population counts included earthworms and the large soil Nematodes; they constituted such a small percentage of the soil forms that the name "Arthropod" was retained as a general designation for the soil forms.

One Application Control for Cattle Lice

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Cattle lice are serious pests of dairy cows during the winter in New York. Nearly every herd is annoyed to some degree by their presence and often as high as 75 per cent of the animals in a herd carries moderate to heavy infestation of one or more of the louse species. Considerable loss to the dairy farmer occurs annually because of these pests. Lowered production, lack of condition of the animals infested, irritation to and uneasiness of the animals infested are attributable to lice.

In the fall of 1947 a program was initiated at New York State College of Agriculture to find a single spray treatment for seasonal control of these parasites. A secondary objective was to determine whether spray applications to dairy cows in barns under winter conditions was practical. This paper reports the results of three seasons of louse control work on dairy farms in the vicinity of Ithaca, New York. The results of the preliminary tests of 1947–48 are not reported because the materials used were later dropped.

Importance of the Species.—In 1950 a method was devised for making counts on field collected samples. This method employs a filter flask, Büchner funnel and a water aspirator pump. The samples are run through 10 per cent KOH to remove the hair, filtered and counted. Following in table 1 is a calculated square inch population index for the four species occurring in New York. The samples were collected from the areas of densest population in all cases, Each sample was from a 2 inch square area.

Although it is noted that *Bovicola bovis* has a higher population index, it is believed that *Solenoptes capillatus* is the species of most economic importance. It is closely followed by *Linognathus vituli* and *B. bovis* would rank third. *Haematopinus eurysternus* is seldom of any importance except in relatively few isolated cases. *L. vituli* is found more frequently and is more likely to be over a larger area of the animal's body than any of the other species. It is not found so frequently in dense populations as in *S. capillatus*. The figures in table 1 would seem to belie this but the population index shown was raised by two samples taken from unusually heavy infestations.

Table 1.—Population index for cattle lice in New York. 1950–51 Season.

Species	Dates	No. of Samples	Square Inch[1] Population Index	Range
Bovicola bovis	Jan. 17–Mar. 26	8	357	70–859
Solenoptes capillatus	Nov. 27–Mar. 10	12	255	18–756
Linognathus vituli	Nov. 10–Mar. 10	10	220	17–797
Haematopinus eurysternus	Dec. 5–Mar. 26	3	86	34–125

[1] All motile stages.

Materials Tested.—*1948–49 Season.*—The materials tested and the formulations used in 1948–49 were: DDT—4 lbs. of 50 per cent wettable powder per 100 gallons: benzene hexachloride[2] —1 lb. of 25 per cent gamma isomer per 100 gallons; rotenone and sulfur—1 lb. of 5 per cent rotenone to 10 lbs. of wettable sulfur per 100 gallons; chlordane—1 quart of 74 per cent emulsion per 100 gallons.

1949–50 Season.—The materials and formulations used in 1949–50 were: chlordane—1 quart of 74 per cent emulsion per 100 gallons; lindane—1 lb. of 25 per cent per 100 gallons; rotrate (wettable 5 per cent rotenone and other cube resins)—1 lb. per 100 gallons.

1950–51 Season.—The materials and formulations used in 1950–51 were: chlordane—1 quart of 72 per cent emulsion per 100 gallons; lindane—1 lb. of 25 per cent per 100 gallons; rotrate—1 lb. of 5 per cent per 100 gallons; pyrenone[3]—1 gallon per 100 gallons.

Application—Application was made with two different high pressure sprayers. A large 150 gallon truck mounted sprayer developing about 400 pounds pressure was used when there was no danger of freezing during the 1948–49 and 1949–50 seasons. A smaller sprayer of 15 gallon capacity developing 200 pounds pressure was used when there was danger of the larger sprayer freezing. The small sprayer was mounted on two wheels and was rolled into the barn while the treatment was made. It was used exclusively during the

[1] Acknowledgments: The guidance and suggestions of Dr. H. H. Schwardt during the course of the work reported herein are gratefully acknowledged.

[2] High gamma product containing small amounts of the other isomers. Not lindane as now designated.

[3] *Pyrenone 143.*

1950–51 season since the results of the two previous seasons had shown no difference due to the lower pressure.

The same spray rod was used with both machines. It consisted of a pistol grip shut-off valve[4] with a swivel connecting to the hose. The rod was made of three-eighths inch pipe with 2 orchard nozzles set at right angles and spaced about 12 to 15 inches apart. The nozzles were equipped with number 5 discs, six hole whirl plates, and strainers. The spray cones overlapped at about 12 to 18 inches from the nozzle. The working distance from the animal's skin was in the zone where the spray cones overlapped. The pistol grip and nozzles were set 180 degrees apart for greater ease of handling while spraying the sides and underlines of the animals.

Attention was given to complete coverage in all instances. About 6 to 8 quarts of spray was applied per mature animal. The treatment was applied as the animals stood in the stanchions though some calves were sprayed in pens. All animals in every herd, except very young calves, were treated.

EVALUATION OR RESULTS.—The meth-

[4] John Bean Co.

Table 2.—Control results for 1948–49.

HERD	NUMBER	TREATMENT	MATERIAL	SPECIES[9] BEFORE	CHECKING DATE	SPECIES[9] AFTER	DAYS OF CONTROL	RESULTS
1	60	11/17/48	DDT .25%[10]	*L. vituli*	2/2/49	—		
					3/10	—		
					4/7	*S. capillatus*		
					5/5	—	141—	Satisfactory
2	52	11/19	DDT .25%	*L. vituli*	2/2	*L. vituli*	75—	Unsatisfactory[1]
3	48	11/19	DDT .25%	—	2/2	*L. vituli* *S. capillatus*		
					3/10	—		
					4/7	*L. vituli*	75—	Unsatisfactory
4	10	11/19	DDT .25%	—	2/5	—		
					4/7	*S. capillatus*		Unsatisfactory
					5/5	*S. capillatus*	139—	
5	25	11/20	Rotenone-sulfur 1:10:100	—	2/2	*S. capillatus*		
					3/10	*S. capillatus*		
					4/7	*S. capillatus*		Unsatisfactory
					5/5	*S. capillatus*	74—	
6	42	11/20	Rotenone-sulfur 1:10:100	—	2/2	—		
					3/10	—		
					4/7	—		
					5/5	—	166+	See footnote[2]
7	41	11/20	Rotenone-sulfur 1:10:100	—	2/5	—		
					3/10	*L. vituli*		
					4/7	*L. vituli*		Unsatisfactory[3]
					5/5	*L. vituli*	110—	
8	44	—	Rotenone-sulfur 1:10:100	—	2/12	—		
					3/11	*L. vituli*		Unsatisfactory[4]
					5/12	*L. vituli*		
9	45	12/3	BHC .03%	*L. vituli*	2/5	*L. vituli* *S. capillatus*		
					3/10	*S. capillatus* *H. eurysternus*		
					4/7	*H. eurysternus* *S. capillatus* *L. vituli*		
					5/5	*L. vituli* *S. capillatus*		Unastisfactory
						H. eurysternus	64—	
10	65	12/4	BHC .03%	*L. vituli*	2/2	*L. vituli*	60—	Unsatisfactory
12	67	12/11/48	BHC .03%	—	2/2	—		
					3/10	—		
					4/7	*L. vituli*		
					5/5	*H. eurysternus*	117—	Satisfactory[5]

Table 2. (*Continued*)

Herd	Number	Treatment	Material	Species[9] Before	Checking Date	Species[9] After	Days of Control	Results
13	51	12/28	Chlordane 0.25%	*B. bovis*	2/12	—		
					3/11	—		
					4/8	—		
					5/10	—		
14	15	12/28	Chlordane 0.25%	—	2/12	—	139+	Excellent
					3/11	—		
					4/8	—		
					5/12	—	157+	Excellent[6]
15	18	12/28	Chlordane 0.25%	Some lice	2/12	—		
					3/11	—		
					4/8	—	101+	Excellent
16	38	12/29	Chlordane 0.25%	*B. bovis*	2/5	—		
				S. capillatus	3/10	—		
				H. eurysternus	4/7	*L. vituli*		
					5/3	*L. vituli*	99−	Satisfactory[7]
17	27	2/10/49	Chlordane 0.25%	—	3/11	—	88+	Satisfactory
19	16	2/10	Chlordane 0.25%	*B. bovis*	3/1	—		
				S. capillatus	4/8	—		
					5/12	—	91+	Excellent
20	38	2/15	Chlordane 0.25%	*B. bovis*	3/11	—		
				L. vituli	4/8	—		
					5/12	—	86+	Excellent
22	60	2/15	Chlordane 0.25%	*B. bovis*	3/11	—		
				L. vituli	4/8	—		
				S. capillatus	5/12	—	89+	Excellent
23	57	2/17	Chlordane 0.25%	*L. vituli*	3/10	—		
					4/7	—		
					5/5	—	77+	Excellent
24	11	2/17	Chlordane 0.25%	*L. vituli*	4/8	—	50+	Excellent
25	75	2/25	Chlordane 0.25%	*B. bovis*	3/10	—		
				L. vituli	4/7	—		
				S. capillatus	5/5	—	69+	Excellent
26	35	2/25	Chlordane 0.25%	*B. bovis*	4/7	—		
					5/5	—	69+	Excellent
27	27	3/8	Chlordane 0.25%	*B. bovis*	4/8	—		
					5/12	—	65+	Excellent
28	5	3/2	Chlordane 0.25%	*B. bovis*	4/20	—		Unsatisfac-
				L. vituli	5/12	*L. vituli*	71−	tory[8]
29	34	3/22	Chlordane 0.25%	*B. bovis*				
				L. vituli	4/8	—		
				H. eurysternus	5/10	—	49+	Excellent
11	18	12/28/48	BHC	*L. vituli*	2/12	—		
		1/7/49	0.03%		3/11	—		
					4/8	—		
					5/10	—	123+	Excellent
21	15	2/15	BHC	*B. bovis*	3/11	—		
		2/26	0.03%	*L. vituli*	4/8	—		
					5/12	—	75+	Excellent

Total number animals in tests—1029

[1] Owner dusted animals pointed out to be infested after the first check.
[2] This herd had no history of lice.
[3] Level of reinfestation heavy.
[4] Infested calves brought in from elsewhere.
[5] Level of reinfestation extremely light.
[6] Based on past history of lice and knowledge of populations in untreated herds.
[7] Rated satisfactory even though some reinfestation, note that three species present before treatment.
[8] Contact with infested animals.
[9] The apparent discrepancy between species present before and after is due to low numbers present before, which can be easily missed on examination and the fact that it is physically impractical to examine each individual animal in every herd. Experience has shown that herds in which nothing was seen on first examination may later develop a heavy infestation.
[10] Percentage calculated on the weight basis.

Table 3.—Summary of reinfestation in nine herds at 3, 5, and 12 months after treatment.

Herd	Date Treated	Material	Species Before	Date Checked	Species After	Remarks
9	12/3/48	BHC 0.03%	*L. vituli*	5/5/49	*L. vituli* *S. capillatus* *H. eurysternus*	Control unsatisfactory
				12/3/49	*H. eurysternus* *S. capillatus* *L. vituli*	Infestation remained
11	12/28/48 1/7/49	BHC 0.03%	*L. vituli*	5/10/49	—	Control excellent
				12/21/49	—	No reinfestation
13	12/28/48	Chlordane 0.25%	*B. bovis*	5/10/49	—	Control excellent
				12/27/49	*L. vituli* *S. capillatus*	Reinfestation[1]
14	12/28/48	Chlordane 0.25%	—	5/12/49	—	Control excellent
				12/27/49	—	No infestation
16	12/29/48 (May '49)	Chlordane 0.25%	*B. bovis* *S. capillatus*	5/3/49	*L. vituli*	Control satisfactory
		BHC 0.046%[2]	*H. eurysternus*	12/22/49	*L. vituli* *S. capillatus*	Reinfestation[3]
22	2/15/49	Chlordane 0.25%	*B. bovis* *L. vituli* *S. capillatus*	5/12/49	—	Control excellent
				12/27/49	*L. vituli*	Reinfestation
23	2/17/49	Chlordane 0.25%	*L. vituli*	5/5/49	—	Control excellent
				12/22/49	—	No reinfestation
25	2/25/49	Chlordane 0.25%	*B. bovis* *L. vituli* *H. eurysternus*	5/5/49	—	Control excellent
				3/21/50	*S. capillatus*	Reinfestation[4]
29	3/22/49	Chlordane 0.25%	*B. bovis* *L. vituli* *H. eurysternus*	5/10/49	—	Control excellent
				12/27/49	*L. vituli* *S. capillatus*	Reinfestation[4]

[1] Young unsprayed bull brought into herd.
[2] Mange treatment. 2 applications .046 per cent gamma BHC at 10 day interval.
[3] Owner pastures heifers with cattle from other herds.
[4] Very low.

od used for evaluating the results was a notation of species found in the herd before and after spraying. Approximately monthly examinations were made after spraying and a final examination and rating was given after the last check in late April or early May. In all cases animals known to be infested before treatment were examined on each subsequent check as were others in the herd. Examination was made with the aid of a headflashlight and species identified on the spot. Areas most likely to be infested were chosen for examination.

No attempts were made to take actual counts because it was impractical to do so. An arbitrary system for establishing per cent mortality seemed inadvisable because of personal bias. Final ratings of excellent, satisfactory, and unsatisfactory were assigned after the final check. No lice were found on animals examined in herds rated excellent; some lice were present in herds rated satisfactory but probably an insufficient number to cause loss; a rating of unsatisfactory was given

Table 4.—Control results for 1949–50.

HERD	TREAT-MENT	MATERIAL AND CONC.	SPECIES BEFORE	DATE OF CHECKING	SPECIES AFTER	PERIOD OF CONTROL	RESULTS
1	12/22/49	Chlordane 0.25%	*B. bovis* *L. vituli* *S. capillatus*	3/21/50 5/18	*L. vituli* —	147+	Excellent
2	12/22	Chlordane 0.25%	*L. vituli* *S. capillatus*	3/21 5/8	— —	137+	Excellent
8(9)[4]	12/22	Chlordane 0.25%	*L. vituli* *S. capillatus* *H. eurysternus*	3/21 5/8	*L. vituli* *S. capillatus* *L. vituli* *S. capillatus*	89−	Satisfactory[1]
3(16)	12/22 1/2	Lindane 0.03%	*L. vituli* *S. capillatus*	3/21 5/8	— —	137+	Excellent
4	12/23 1/2	Rotenone[5] 0.125%	*B. bovis* *L. vituli* *S. capillatus* *H. eurysternus*	3/21 5/8	*H. eurysternus* *B. bovis* *L. vituli* *S. capillatus*	78−	Unsatisfactory[2]
5(13)	12/28 1/4	Rotenone[5] 0.125%	*L. vituli* *S. capillatus*	3/21 5/8	— *S. capillatus*	124−	Satisfactory
10(29)	12/28 1/4	Rotenone 0.125%	*L. vituli* *S. capillatus*	2/24	*S. capillatus*	57−	Satisfactory
6	12/23	Rotenone[5] 0.125%	*B. bovis* *S. capillatus*	3/21 5/8	*S. capillatus* *S. capillatus*	88−	Unsatisfactory
9	12/23	Rotenone[5] 0.125%	*B. bovis* *S. capillatus*	2/24	*B. bovis* *L. vituli* *S. capillatus*	63−	Unsatisfactory[3]

Total number of animals in tests approximately—270.

[1] Scattered, light infestation.
[2] Some animals received only one application because owner sold and bought between treatments. Interval between treatments too short also.
[3] Interval between treatments too short.
[4] Numbers in parenthesis designates 1948–49 herd number.
[5] A rotenone compound "*Rotrate*."

to herds in which the population of lice was causing discomfort to the animals and showing evidence of building up again.

No control checks were possible under the conditions of the experiment. All the work was done on dairy farms where isolation of checks was impractical and undesirable to the farmer.

RESULTS.—The results for the 1948–49 season are shown in table 2.

The important points shown by the results for this season were (1) the effectiveness of chlordane in controlling all species with a single application, (2) two applications of benzene hexachloride were necessary for equal control, (3) the poor results obtained with DDT and rotenone and sulfur.

In making a local survey for test herds in December of 1949, herds No. 9, 11, 13, 14, 16, 22, 23, 25 and 29 treated in the 1948–49 season were revisited to determine their status of reinfestation. Presented in table 3 are the results of examinations made December 3, 21, 22, 27, 1949 and March 21, 1950.

While no more than seasonal control has been attempted, it is noted from the above data that there is an apparent eradication of *Bovicola bovis* in all of the five herds in which it occurred. There is also an apparent eradication of *Linognathus vituli* in three herds; *Solenoptes capillatus* in one herd, and *Hæmatopinus eurysternus* in three instances. There is no doubt that the eradication may be more apparent than absolute just on the basis of the examinations. However, the time element involved between the date of treatment and the date of the last check swings the balance in favor of absolute eradication. The tenacity of *L. vituli* and *S. capillatus* in these herds is noteworthy.

The results for the 1949–50 season are presented in table 4.

The control results for 1949–50 continue to illustrate the effectiveness of one application of chlordane or two of lindane.

The results for the 1950–51 season are presented in table 5.

The results for the 1950–51 season continue to illustrate the effectiveness of chlordane with one application and lindane with two applications. This season's results alone show that two applications of rotrate was superior to two of lindane. Pyrenone at the rate used is unsatisfactory as a single application treatment particularly against *Linognathus vituli* and *Solenoptes capillatus*, although the initial reduction in population is good.

DISCUSSION.—It is concluded from the three seasons' work in 41 herds totaling 1811 animals that: (1) Chlordan eat .25 per cent is the only material tested which gave excellent seasonal control of all species of cattle lice with one spray application; (2) Lindane at .03 per cent gave excellent results in most cases with two applications; (3) Rotenone at .125 per cent of rotenone gave good results with two applications; (4) Pyrenone at 1 gallon per 100 gallons was not satisfactory for seasonal control at one application although the initial kill was very good; (5) In no instance was there any ill effect attributable to the spraying of the cows in the barn in cold weather. Barn temperatures averaged approximately 40° F. during period when spray applications were made.

Rotrate and pyrenone may have some advantage from the toxicity and milk contamination standpoint although no ill

Table 5.—Control results for 1950–51.

Herd	Number	Treatment	Strength of Material	Species Before	Dates Checked	Species After	Days of Control	Results
1	40	1/17/51	Chlordane 0.24%	*B. bovis* *S. capillatus*	1/30/51	—		
					3/10/51	—		
					4/17/51	—	90+	Excellent
2	55	1/18/51	Chlordane 0.24%	*B. bovis* *S. capillatus*	3/10/51	—		
					4/14/51	—	86+	Excellent
3	33	1/18/51	Chlordane 0.24%	*B. bovis* *S. capillatus* *L. vituli*	1/30/51	—		
					3/10/51	—		
					4/17/51	—	89+	Excellent
4	25	1/24/51	Chlordane 0.24%	*L. vituli*	2/4/51	—		
					3/10/51	—		
					4/14/51	—	80+	Excellent
5	63	1/16/51 1/27/51	Lindane 0.03%	*S. capillatus*	1/27/51	*S. capillatus* (N)		
					3/10/51	—		
					4/14/51	*L. vituli*	77−	Satisfactory
6	45	2/4/51 2/15/51	Lindane 0.03%	*L. vituli*	2/15/51	—		
					3/10/51	—		
					4/14/51	*L. vituli*	58−	Satisfactory
7	15	2/12/51 2/24/51	Lindane 0.03%	*S. capillatus* *L. vituli*	2/24/51	*L. vituli* (N) *S. capillatus* (N)		
					3/10/51	—		
					4/14/51	—	49+	Excellent
8	15	1/19/51 1/30/51	Rotenone[2] 0.125%	*B. bovis* *S. capillatus* *L. vituli*	1/30/51	*S. capillatus* (N)		
					3/10/51	*L. vituli*		
					4/14/51	—	74+	Excellent
9	35	2/1/51 2/12/51	Rotenone[2] 0.125%	*S. capillatus*	2/12/51	*S. capillatus* (N)		
					3/10/51	—		
					4/14/51	—	92+	Excellent

Table 5.—(*Continued*)

HERD	NUMBER	TREATMENT	STRENGTH OF MATERIAL	SPECIES BEFORE	DATES CHECKED	SPECIES AFTER	DAYS OF CONTROL	RESULTS
10	23	2/4/51 2/15/51	Rotenone[2] 0.125%	*B. bovis* *S. capillatus* *L. vituli*	2/15/51	—		
					3/10/51	—		
					4/14/51	—	58+	Excellent
11	50	12/22/50	Pyrenone[1] 1 gal/100 gal.	*L. vituli*	1/30/51	*L. vituli*		
					3/10/51	*L. vituli* *S. capillatus*	78−	Unsatisfactory
12	10	12/20/50	Pyrenone 1 gal/100 gal.	*L. vituli*	2/12/51	*L. vituli*		
					3/1/51	*L. vituli* *S. capillatus*	71−	Unsatisfactory
13	60	12/5/50	Pyrenone 1 gal/100 gal.	*S. capillatus* *L. vituli* *H. eurysternus*	1/30/51	*H. eurysternus*		
					3/10/51	*G. eurysternus*	95−	Unsatisfactory
14	43	1/17/15	Pyrenone 1 gal/100 gal.	*S. capillatus*	1/30/51	*S. capillatus*		
					3/10/51	*S. capillatus*	52−	Unsatisfactory

Total of 512 animals in tests.

[1] Pyrenone T-143 containing:
Petroleum oil
Polyoxyethylene sorbitol mixed ether ester
Technical piperonyl butoxide—10%
Pyrethrins—1%
Technical piperonyl butoxide consists of 80% of (butyl carbityl) (6 propyl piperonyl) ether and 20% of related compounds.

[2] A Rotenone compound. (*Rotrate*)

(N)—nymphs present at time of 2nd treatment.

effects have ever been noted after treatment with chlordane and lindane at the concentrations used. Radeleff & Bushland (1950) cite the toxic levels of these materials and from their experiments it can be seen that the concentrations used in these tests are well below the toxic level. Bushland *et al.* (1950) cite the probable meat and milk contamination resulting from such applications. The use of chlordane hinges largely on the development of a specific analytical technique for determining the amount which is likely to occur in milk after spraying.

Two applications of .046 per cent lindane are currently recommended at the New York State College of Agriculture for the control of mange on cattle. Lindane at the same level is recommendable for louse control also where the problems are concurrent. Application of lindane for lice as for mange acts against any mange mites which may be present in sub-clinical cases.

SUMMARY.—Three seasons' work on louse control in dairy herds in New York are reported herein. Of the naterials tested only 0.25 per cent chlordane gave excellent seasonal control with one application. Lindane and rotrate at .03 and .125 per cent respectively when applied twice at an interval of 11 days gave excellent to good seasonal control. Pyrenone at one application was unsatisfactory. In no instance were there any toxic effects from the materials as used nor any ill effects from spraying dairy cows in the barn during winter.

LITERATURE CITED

Bushland, R. C., H. V. Claborn, H. F. Beckman, R. D. Radeleff and R. W. Wells. 1950. Contamination of meat and milk by chlorinated hydrocarbon insecticides used for livestock pest control. JOUR. ECON. ENT. **43**(5): 649–53.

Radeleff, R. D. and R. C. Bushland. 1950. Acute toxicity of chlorinated insecticides applied to livestock. JOUR. ECON. ENT. **43**(3): 358–64.

Experiments with Screw-Worm Flies Sterilized by X-Rays[1]

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Flies of the screw-worm, *Callitroga americana* (C. & P.), cause serious damage over much of the United States each summer but in cold winters the flies survive only in subtropical regions. Flies that annually migrate over the West and Middle West spring from stocks that overwinter in Mexico and adjoining states. However, screw-worm flies that infest the East and Southeast come from a stock that during most winters survives only in southern Florida. Field observations indicate that the winter population of flies in Florida is not high. The Florida fly population is isolated from screw-worm areas elsewhere in the country and, if it could be eliminated, screw-worms could be kept out of the eastern states.

Present measures of screw-worm control depend upon management practices by the livestock grower and consist chiefly of avoiding wounds in domestic animals and treating infested wounds with insecticides. Such practices curtail screw-worm damage, but do not suffice to eradicate the pest because flies find enough wounds in wild animals and neglected domestic livestock to survive under winter conditions and to increase tremendously over a large area in the summertime.

Many years of general observations by Bureau workers rearing colonies of screw-worm flies have indicated that the flies mate rather infrequently. Therefore, it seemed possible that they might be eradicated in southern Florida by introducing large numbers of sterilized males in the wintertime when the natural population is barely numerous enough to survive.

It has been recognized that insects can be sterilized by irradiation with x-rays. Runner (1916) found that cigarette beetles, *Lasioderma serricorne* (F.), when irradiated as adults subsequently laid infertile eggs. Geneticists using x-rays to induce mutations in *Drosophila* found that the flies were sterilized by overdoses of irradiation. Muller (1928) reported that untreated female *Drosophila* flies mated to heavily treated males laid eggs that failed to hatch. He interpreted the mortality of eggs fertilized by irradiated sperm as resulting from chromosomal changes which he described as a "dominant lethal" effect.

This report describes laboratory experiments conducted during 1950 at the Kerrville, Texas, laboratory of the Bureau to determine the possibility of sterilizing screw-worm flies by x-ray and the effects on the fertility of normal flies held in cages with various proportions of sterilized insects.

Materials and Methods.—*Test insects.*—The test insects were screw-worm flies taken from the laboratory colony. The adult flies are kept in screen cages and fed on water, honey, and, during the preoviposition period, lean beef. Mating begins when the flies are 2 days old and at 6 days of age most of the females are ready to lay fertile eggs.

To obtain eggs, flies approximately 1 week old are confined in shell vials containing small pieces of lean beef, and are held for 2 hours at 90° to 100° F. The gravid females deposit their eggs in masses of approximately 200 on or adjacent to the meat. The egg masses are transferred to moist paper in a petri dish and, depending upon temperature, they hatch in 12 to 24 hours. The larvae are reared at approximately 95° on a nutritional medium composed of lean beef, citrated beef blood, and water with a small amount of formaldehyde added to retard putrefaction. After 6 days the larvae become full grown and leave the food to pupate in sand.

The pupae are held at room temperature and a relative humidity of almost 100 per cent, and the adults emerge in about 8 days.

The insects used for irradiation were adults less than 2 days old, pupae less than 2 days old, and pupae within 2 days of emergence. In mating experiments, flies sterilized by x-rays were caged with untreated flies that had been

[1] Presented at the annual meeting of Southwestern Branch of the American Association of Economic Entomologists at Dallas, Texas, March 1 and 2, 1951.

[2] The work reported in this paper was undertaken at the suggestion of E. F. Knipling, who proposed that the release of sterilized flies might be utilized in the control of screw-worms, *Callitroga americana* (C. & P.), in selected areas.

reared on the nutritional medium, and in some final tests flies reared on wounded sheep were used to represent the normal population.

Flies to be used in mating experiments were separated according to sex when less than 48 hours old to assure that they were not previously mated. The sexes were determined by anesthetizing young adults with carbon dioxide and examining each specimen individually. Within treatment groups, males were placed in one holding cage and females in another, and the sexes were maintained separately prior to the experiments.

As a check on the accuracy of the sexing procedure, enough of the females were separated so that a control group of supposedly virgin females would be left in the holding cage for "egging"—that is, forcing oviposition—at the termination of the experiment.

X-ray Equipment.—The test insects were irradiated at Brooke Army Hospital by Lt. Col. W. E. Barry, M. C., U. S. Army, Brooke Army Medical Center, Fort Sam Houston, Texas. According to Colonel Barry: "The equipment used was a deep therapy unit. The factors used were 200 kilovolts, 20 milliamperes, one-fourth copper inherent filtration, no added filter, half-value layer of 0.9 mm. copper, 20×20 cm. field, 50 cm. distance, delivering 112 r [roentgens] per minute in air. The total doses were given as a single exposure. The total r dose referred to throughout this paper refers to the total r dose *in air*. According to published standard data, secondary irradiation and 'back scatter' increase the actual tissue dose (flies and pupae) by 50 per cent so that they received a 50 per cent larger dose of irradiation than indicated by the air dose. For x-raying, the insects were exposed in shallow plastic boxes for a sufficient time to obtain the desired dosage of direct irradiation."

IRRADIATION EXPERIMENTS.—*Adult Flies.*—Adult flies less than 2 days old were irradiated with dosages of 1500; 2500; and 5000 r of direct irradiation. The flies were transferred in shell vials from the rearing cage to plastic boxes for irradiation in groups of approximately 300. After being x-rayed, each treatment group was divided and caged as follows (50 flies of each sex): Irradiated (R) males plus normal (N) females; R males plus R females; N males plus R females. When the flies were 12 days old the surviving females were egged by the usual procedure.

The highest dosage, 5000 r direct irradiation, had no effect on the fertility or fecundity of the females, as they laid as many eggs as the controls and all hatched. Normal females mated to irradiated males produced normal numbers of eggs, but most of the eggs from flies mated with males given 5000 r were infertile. Less than 1 per cent of the eggs in any egg mass hatched. About 10 per cent of the eggs from flies mated to males receiving 2500 r hatched, whereas there was a 70-per cent hatch of eggs from normal females mated to males treated with 1500 r.

A dosage of 2500 r direct irradiation was approximately 90 per cent effective in sterilizing males and 5,000 r produced almost complete male sterility.

Mortality records were taken at the time the flies were egged. Both males and females treated with 2500 and 1500 r lived as well as the controls. There were fewer survivors among the flies treated with 5000 r, but the differences were not great enough to be considered significant on the basis of a single test.

Young Pupae.—Pupae ranging in age from 16 to 48 hours were irradiated in groups of 500. At 500 and 1500 r direct irradiation almost all the flies emerged; at 2500 r only 47 males and 125 females emerged out of an expected 250 of each sex; and at 5000 r only 3 females emerged and they died shortly thereafter.

The flies from the irradiated pupae were separated according to sex within 2 days of emergence, and when 5 days old were used in mating experiments. Eggs were obtained from the females when they were 8 days old. The highest dosage which the flies survived (2500 r) appeared to have no effect on their fertility or fecundity, as irradiated females mated to normal males laid normal numbers of fertile eggs, and normal females mated with irradiated males also laid eggs that were 100 per cent fertile.

Old Pupae.—Pupae within 2 days of emergence were irradiated in the manner described above for young pupae. Within 2 days after the flies had emerged, the sexes were separated and the first series of mating experiments was made with 6-

Table 1.—Egg masses produced and fertility of eggs in mating experiments with flies irradiated as 6-day-old pupae. (Each mating consisted of 75 males and 75 females.)

Direct Irradiation (Roentgens)	Mating[1]		First Egging (Flies 8 days old)		Second Egging (Flies 18 days old)	
	Males	Females	Number of Egg Masses[2]	Per Cent Hatch	Number of Egg Masses	Per Cent Hatch
5000	R	R	4	0	1	0
	R	N	60	0	0	—
	N	R	7	2	0	—
2500	R	R	17	[3]	3	0
	R	N	50	[3]	3	[3]
	N	R	17	85	2	100
1500	R	R	45	15	6	5
	R	N	50	10	4	25
	N	R	50	100	8	100
500	R	R	55	100	10	100
	R	N	50	100	10	100
	N	R	50	100	5	80
0	N	N	45	100	—	—
	N	N	40	100	—	—
	—	N	40	0		

[1] R = irradiated flies; N = normal flies.
[2] Numbers ending in 5 or 0 represent estimates, as accurate counts were difficult when several egg masses were laid together.
[3] Less than 0.5 per cent of eggs hatched.

day-old flies, 75 of each sex being used for each cage. The flies were left together for 2 days, and were then egged and returned to their mating cages. Ten days later the experiment was terminated by egging the flies a second time. The results are summarized in table 1.

Irradiation with 500 *r* had no effect on the fertility of either sex. Females receiving as much as 1500 *r* laid normal numbers of fertile eggs when mated to normal males. Normal females mated to males treated with 1500 *r* direct irradiation produced eggs of which only about 10 per cent hatched, but a dosage of 2500 *r* was required to sterilize most of the males. That dosage of 2500 *r* also affected the females, as they laid only about one-third the normal number of eggs. However, most of the eggs from irradiated females mated to normal males hatched.

A dosage of 5000 *r* still further reduced the fecundity of female flies, as they laid only about 10 per cent of the normal number of egg masses, and the egg masses averaged only about 40 eggs instead of the normal 200. In the case of irradiated females mated to normal males there was only about 2 per cent hatch of the few eggs produced. Thus for practical purposes a dosage of 2500 *r* sterilized the males and twice that dosage sterilized the females.

In a subsequent experiment, pupae within 2 days of emergence were subjected to irradiations of 3000; 3500; 4000; 4500; and 5000 *r*. The females were separated within 2 days of emergence and when 3 days old were mated with normal males. At the age of 10 days the females were egged with the following results:

Number of Females	*r*-Dose	Eggs Laid	Masses Hatched
77	3000	5	1
109	3500	7	2
81	4000	4	2
101	4500	0	—
100	5000	4[1]	0

[1] Egg masses less than one-fifth normal size.

LONGEVITY OF IRRADIATED FLIES.—During the course of the experiment summarized in Table 1 mortality records were taken daily in the various cages. In general the death rates were quite uniform, so to save space only the mortality records for flies 14 and 18 days old are shown in table 2.

A dosage of 5000 *r* applied to 6-day-old pupae appeared to reduce the longevity of the flies. Flies from pupae treated with 2500 *r* or less direct irradiation lived as long as the untreated controls.

Several months later additional observations were made on the effects of 5000 *r* irradiation. A culture of 6-day-old pupae was divided into two groups. One group was irradiated and the other served as

Table 2.—Per cent mortality of screw-worm flies which emerged from pupae irradiated when 6 days old. (150 flies in each treated set and 450 in each untreated set.)

Irradiation (Roentgens)	14 Days after Emergence		18 Days after Emergence	
	Males	Females	Males	Females
5000	90	69	97	76
2500	77	37	95	62
1500	78	45	93	71
500	37	21	71	47
0	70	52	90	76

untreated controls. When the flies emerged, 400 untreated flies were placed in one cage and 400 irradiated flies in another. Two other cages representing less crowded conditions were stocked with 120 flies each, one cage with untreated and the other with irradiated insects.

Mortality records were taken daily, and the totals observed after 7 and 14 days are tabulated below:

Cage Population	Per Cent of Flies Dead After			
	7 Days		14 Days	
	Males	Females	Males	Females
400 untreated	22	10	56	46
400 irradiated	53	31	96	87
120 untreated	22	12	53	37
120 irradiated	63	33	93	68

These results confirmed the earlier observation that screw-worm flies irradiated with 5000 *r* as 6-day-old pupae were not so long-lived as untreated insects.

Mating Experiments.—*Experiments with flies reared in a medium.*—For a preliminary experiment on the effects of adding sterilized males to a fly population, a culture of medium-reared pupae 6 days old was divided into two groups. One group was allowed to emerge normally, whereas the other was treated with 2500 *r* of x-rays to produce sterilized males. When these males were 2 days old, various numbers were added to cages containing five normal males and five normal females from the same culture. When the flies were 9 days old the females were egged. Females from cages in which sterilized males outnumbered normal males by a ratio of 5 to 1 or greater all laid infertile eggs.

In another experiment pupae were exposed to 5000 *r* irradiation to produce sterilized flies of both sexes. These insects were caged with normal flies from the same culture. The sexes were separated when the flies were 2 days old, and when 4 days old the insects were caged in mating experiments. Five days later the experiments were terminated by obtaining eggs and noting their fertility.

The experiment was conducted with duplicate cages for each combination of normal and sterilized flies. The results were checked by a subsequent experiment in which a single series of caged populations was used, some of the combinations duplicating those previously studied.

The results of the two experiments, as summarized in table 3, suggested that the addition of sterilized flies to a normal population in such a ratio that the sterile flies outnumber the normal flies 10 to 1 resulted in most of the normal females producing infertile eggs.

Table 3.—Effect on fertility of female screw-worm flies, reared in a medium or in a wound, of introducing various numbers of sterilized flies in a caged population.

Cage Population[2]	Number of Cages	Egg Masses		Per Cent Fertility
		Laid	Hatched	
Flies reared in medium				
0	3	21	21	100
10 males plus 10 females	2	11	7	64
20 males	1	4	3	75
20 females	1	7	6	86
20 males plus 20 females	3	18	12	67
50 males	2	11	4	36
50 females	2	10	5	50
50 males plus 50 females	3	22	6	27
100 females	1	8	2	25
100 males plus 100 females	3	23	3	13
Flies reared in wounds[1]				
0	4	26	24	93
20 males	4	24	9	38
20 females	4	30	30	100
20 males plus 20 females	4	27	7	30
50 males	4	15	2	13
50 females	4	30	27	90
50 males plus 50 females	4	23	6	26
100 males	4	17	2	12
100 females	4	30	15	50
100 males plus 100 females	4	30	0	0

[1] Summary of 2 experiments, each made in duplicate.
[2] Ten normal males plus 10 normal females plus indicated number of sterilized flies.

Experiments with Flies Reared in Wounds.—Screw-worm larvae reared on the standard nutritional medium produce flies that are somewhat smaller than flies from maggots reared in wounds of living animals. It is possible that the animal-reared larvae might produce more vigorous males than those from larvae reared *in vitro*. Therefore, the finding that sterilized medium-reared males could successfully compete with normal medium-reared males had to be checked against wound-reared flies, as in nature screw-worms breed exclusively in wounds.

Sheep were wounded and artificially infested with screw-worm larvae from the laboratory colony to rear flies selected to represent a normal population. Simultaneously other larvae from the same source were reared on the nutritional medium. When the pupae were 6 days old the medium-reared insects were sterilized with a dosage of 5000 *r*. All flies were sexed within 2 days of emergence, and the insects were caged in mating experiments when the flies were 4 days old. Five days later the experiment was terminated by obtaining eggs and noting their fertility. When the normal wound-reared population was outnumbered at least 5 to 1 by sterilized flies, the fertility of the normal females was greatly reduced. To check on these encouraging results the experiment was repeated a month later. The data obtained in the two series of tests checked closely and have been combined in table 3.

When only sterilized males were added to a normal population, the fertility of the normal females was decreased by about two-thirds when sterile males outnumbered normal males 2 to 1. When sterile males outnumbered normal males 5 to 1, only one-seventh of the normal females were fertile, and when the ratio was 10 to 1 about one-eighth of the females produced fertile eggs.

When only sterile females were added to the population, all the normal females produced fertile eggs when the ratio was 2 to 1 and most of the normal females produced fertile eggs at a ratio of 5 to 1. However, when sterile females outnumbered normal females 10 to 1, only half the normal females were fertilized.

When equal numbers of both sterilized males and females were added to the normal population, the fertility of the normal females was affected to about the same extent as when only sterilized males were added. The data suggested that the introduction of sterilized females had relatively little effect. That finding is most encouraging if the release of sterilized flies among a natural population should be tried for practical screw-worm control, as it would be much simpler to release both sterilized males and females and avoid the problem of separating the sexes to release only sterilized males.

Table 4.—Fertility of normal females variously caged with normal and sterilized males.

Number of Insects and Conditions Under Which They Were Held	Cage	Egg Masses Produced[1]	Condition of Eggs
200 normal females alone	A	70	Infertile
200 normal females: With 200 irradiated males left together for 12 days	B	100	Infertile
With 200 normal males left together 7 days, then females held separately for another 5 days	C	110	All but 4 fertile
With 200 irradiated males for 7 days, then irradiated males removed and replaced by normal males for 5 additional days	D	105	All but 1 infertile

[1] Estimated as accurately as possible.

OBSERVATIONS ON MATING HABITS OF SCREW-WORM FLIES.—*Mating of Normal Males.*—During the course of the work several experiments were made to determine how frequently males mate. For such tests normal medium-reared flies 4 days old were used. Five virgin males were caged with 100 virgin females, and after 6 days the females were allowed to oviposit in shell vials. Records were taken on the number of egg masses produced and the number hatching.

A total of nine cages, involving 45 males and 900 females, were employed. The 900 females produced 530 egg masses, of which 147, or 28 per cent, hatched. The sex ratio was so arranged that males were provided for only 5 per cent of the females, and as 28 per cent of the females that laid eggs were fertile, it appeared that the average normal medium-reared male mated about five or six times when an abundance of unmated females was constantly available.

Eight other cages were set up in which wound-reared males were similarly confined with normal females, 5 males and 100 females being used per cage. These 800 females produced 560 egg masses, of which 310, or 55 per cent, hatched. Since 55 per cent of the ovipositing females laid

fertile eggs and males were provided for only 5 per cent, it was indicated that the average wound-reared male mated 11 times under the conditions of the experiment.

Mating of Normal Females.—In one experiment with 8-day-old normal flies, 100 virgin males were placed in a cage with 100 previously mated females and this cage was observed simultaneously with one containing 100 virgin males and 100 virgin females. In both cages the males sought the females with equal vigor, but no matings were observed to take place in the cage containing previously mated females, whereas several copulating pairs were noted in the other cage.

An experiment was made to determine whether a female, once mated to a sterilized male, would subsequently mate with a normal male. A culture of 6-day-old pupae was divided and one group treated with 5,000 *r* of x-rays to produce sterilized flies. The untreated pupae produced normal flies, all of which emerged at the same time. When the flies were 1 day old they were placed in one of four cages, and when the females were 13 days old they were allowed to oviposit. The data pertaining to this experiment are given in table 4.

In cage C, four of the 110 ovipositing females were not fertilized during the first 7 days. The one fertile female in cage D may not have mated during the first 7 days while caged with sterilized males, or she may have mated a second time with a normal male. Regardless of the interpretation, the results indicate that there is little likelihood of second matings by female screw-worm flies held under laboratory conditions.

Mating of Sterile Flies.—In setting up the experiments described in the foregoing sections, it was the practice to separate the sexes before the flies were 2 days old and cage various numbers of normal and sterilized flies when the insects were 4 to 6 days old. In such circumstances the males immediately sought to mate with the females and in a cage of 50 or more pairs of flies, as many as 10 copulating pairs were commonly noted within 5 minutes after the sexes were placed together. General observations indicated that sterilized males were as active as normal males and the males sought sterilized females as actively as they did normal females.

FURTHER EXPERIMENTS REQUIRED.—The laboratory cage tests have indicated that female flies in a normal screw-worm population will lay largely infertile eggs if the normal male population is outnumbered 5 or 10 to 1 by sterilized males. Sterilized females can be introduced along with the males without affecting that result.

These results are most encouraging, since the tests were conducted in small cages where the insects had every opportunity to mate and, unlike a natural environment, the sexes were kept in constant proximity. It would seem that since the theory of releasing sterilized males works in cages it should succeed in nature if adequate numbers of sterilized males are properly distributed. However, since conditions in nature are so different from the environment of the laboratory, it is essential that some sort of practical field test be conducted. A field experiment could be made at reasonable expense if the area selected were small and isolated from other screw-worm-infested areas. Such an area might be an irrigated valley in the desert region of Arizona or a small island off the Atlantic Coast.

It would be necessary for entomologists to make a thorough study of the normal screw-worm population in the test area before releasing sterilized flies. A reasonably accurate index of normal fly density could be obtained by artificially infesting animals with screw-worms (no maggots would be allowed to escape to add to the natural population) and counting the flies visiting those wounds. An index of the efficiency of the release of sterilized flies could be obtained by noting the fertility of eggs deposited on the margins of "trap" wounds.

As sterilized females cannot produce normal egg masses, there would be little risk of confusing ovipositing released females with normal flies, but normal females visiting the wounds only to feed or normal males could not always be distinguished (by the character of somewhat larger size or more robust appearance) from released flies.

As an added refinement it might be desirable to add radioactive phosphorus to the diet of the maggots being reared for sterilization so that the released flies could be readily recognized through the use of a Geiger counter. A. W. Lindquist,

of the Corvallis laboratory of the Bureau, has demonstrated the success of this means of identification for other species of blow flies, but some preliminary research would be needed to establish a procedure applicable to screw-worms.

In a small-scale test it would be entirely feasible to release the sterilized insects by a manual scattering of sterilized pupae within a few hours of fly emergence. In large-scale work aircraft would be required for proper distribution of sterilized flies.

SUMMARY.—It was found that screw-worm flies, *Callitroga americana* (C. & P.) could be sterilized by irradiation with x-rays. Sterilization of males was accomplished by irradiating young adult flies, but it was most efficient to irradiate pupae within 2 days of emergence.

When pupae were irradiated, a dosage of 2500 roentgens direct irradiation (plus an additional 50 per cent due to back-scatter and secondary irradiation) sterilized males. A dosage of 5000 roentgens direct irradiation was required to sterilize females, and that treatment also rendered the females incapable of producing normal egg masses.

When sterilized males were confined with normal males and normal females in laboratory cages, most of the normal females did not become fertilized if the sterilized males outnumbered the normal males by a ratio of 5 or 10 to 1. Adding sterilized females to the caged population along with sterilized males did not affect the end result.

Laboratory observations showed that male screw-worm flies will mate as many as 11 times if virgin females are available. Most females mated only 1 time, although mated females remained attractive to males.

To test whether a natural population can be eradicated through release of sterilized flies, it is suggested that sterilized flies be released among a population of normal flies in a limited and isolated screw-worm-infested area, such as an irrigated valley in a desert or on a small island off the Atlantic Coast.

LITERATURE CITED

Muller, H. J. 1928. The problem of genetic modification. Verhandl. der V. Kong. f. Vererb., 1927; [Proc. 5th Internatl. Cong. Genet., Berlin 1927]. Ztschr. f. Induktive Abstam. u. Vererbungslehre., Sup. Bd I: 234–60.

Runner, G. A. 1916. Effect of röntgen rays on the tobacco, or cigarette beetle and the results of experiments with a new form of röntgen tube. Jour. Agr. Res. 6: 383–8

Fly Control Experiments in Massachusetts in 1950

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Housefly abundance in 1950 was much less than during the seasons 1948 and 1949. The flies were very successful in overwintering so that a low but general population appeared early in 1950.

The first flies appeared in late April and breeding occurred in May with the result that fly abundance became appreciable in early June. Control treatments were started about the middle of June, the earliest that has been necessary to date. The abundance of flies lessened by early July in untreated as well as treated areas and continued relatively low throughout the season. The fall weather was unseasonably warm so that flies remained active into early November.

MATERIALS AND METHODS.—The experiments were conducted on the University and Experiment Station grounds. Barns and buildings containing sheep, hogs, cattle, horses and poultry were treated with several insecticidal formulations including methoxychlor, lindane and DDT. These three insecticides were recommended by the U.S.D.A. for use in cattle barns during 1950 (Bishopp & Henderson 1950). A new method, *i.e.* continuous vaporization of insecticides along with conventional methods (Fulton *et al.* 1950) of application was used. The sprays were applied with hand pressure sprayers to selected areas of the barn. The vapor applications were automatically dispersed from electrically heated devices that can be adjusted to disperse and maintain

Table 1.—Effectiveness of vaporized lindane against flies in livestock barns during 1950.

Type of Livestock	Barn Openings Sq. Ft.	Volume Cu. Ft.	Dosage Days	Dosage Gr./20,000 cu. ft./Day	Average Number of Flies per Period Days 1–9	10–19	20–40	41–60	61–80	81–120	121–138	139+
None	Closed	26,400	1–63	2.84	7.5	11	3.5	9.5				
Heifers[1]	Closed		64–138	.27					5.5	5.5	2	
Heifers[1,2] +Beef Stock	288	21,450	1–82 83–138	.59 .95	4.5	13	11.5	19	11.5	4	1	0
Bulls[1,2]	168	15,309	1–73 74–136	.71 1.05	24	27.5	21.5	35	31	13	0	0
Horses	290	18,534	1–124	.50	5.5	5.5	5.5	5.5	5.5	5.5	5.5	0
Horses	236	17,600	1–27 28–151	Spray[3] Spray[3]	23	21.5	42.5	9.5	5.5	7	11	0
Hogs[1]+Sheep	132	26,325	1–145	.45	16.5	33.5	9.5	7	5.5	4.5	0	0
Sheep												
A	120	6,250	1–131	2.34	11	11	5.5	5.5	5.5	2	0	0
B[4]	132	10,000	1–131	None	5.5	21.5	11	11	5.5	3	0	0
C	120	6,250	1–48 49–131	Spray[5] 1.50	16	17.5	43	65	29.5	3.5	0	0

[1] Average number of flies per animal.
[2] Free of hornflies throughout the season.
[3] Spot treatment with 20 grams of lindane on first and twenty-eighth day.
[4] Middle pen, no treatment except dispersal of vapor from pens A & C through 12 sq. ft. openings in partitions.
[5] Spot treatment with 20 grams of lindane on first day.

minute quantities of the insecticide in the atmosphere for desired periods of time. No solvents or carrying agents are required with this method. The barns remained open in the customary manner throughout the season.

The hog and sheep barns were close together and considerably isolated from the remaining barns. The sheep barn was divided into three sections, A, B, and C, by matched board partitions having a single opening. The beef cattle barn sprayed with methoxychlor (Table 2) was likewise isolated from all other barns. The remaining barns and poultry plant were in close proximity and flies could readily disperse from one to the other.

The flies involved were primarily the house fly, although stable flies, blue bottle, latrine, horn flies and borborids or dung flies occurred also.

Estimates of fly population in table 1 were based on counts taken either on the animals (as indicated) or on selected surfaces of the barns. In either case the recorded observations consisted of the average of 2 to 4 repeated counts on favorite resting or feeding areas of the flies.

The seasonal results with the lindane vapor treatments are given in table 1. The spray treatments which contained minute quantities of lindane comparable to the vapor applications are included for comparison.

Results.—Dosages ranging from 0.36 gram to 2.84 grams per 20,000 cu. ft. daily were applied from automatic vaporizers in the different barns. Ususally dos-

Table 2.—Results of spray treatments in livestock buildings.

Livestock in Building	Insecticide Formulation (Wet. Powder)	Spray Conc. Per Cent	Dates of Application	Sq. Ft. per Gallon	Area Treated (Sq. Ft.)	Results
Calves[1]	Lindane 25%	.4	6–27 7–31	450	900	Excellent
Milk Cows	Lindane 25%	.4	7–7 8–18	—	—	Excellent
Beef Cattle[2]	Methoxychlor 50%	2.5	8–31 10–2	300	1500	Good
Chickens and Turkeys	DDT 50%	3.0	6–15 7–6 9–13	300	1400	Fair

[1] All calves over 3 months old sprayed for lice with .03 per cent Lindane (wet. pow.) 8-17-50.
[2] Sprayed for lice with 1 per cent DDT (W. P.) 8-21-50.

ages of about 0.5 gram per 20,000 cu. ft. daily were ample to keep the fly populations at a very low level in less drafty barns. The bull and young stock barns were quite drafty so the dosage was increased by addition of vaporizers to approximately 1 gram daily per 20,000 cu. ft., which quickly reduced the fly population. It is evident that exceedingly minute quantities of the vapor were necessary in the atmosphere for controlling the flies. However, the residual value of this method of application appears to be exceedingly low. In the hog barn, for example, the electricity was accidentally turned off for 2 days resulting in counts of 75 flies per animal at the end of that period.

The bulls and young stock were retained in barns with adjoining pens throughout the season. They were entirely free of horn flies, which were quite prevalent on untreated cattle in the field during 1950. It has been necessary to treat the bulls and young stock in these pens to eliminate horn flies during previous seasons. Stable fly abundance did not develop about the vapor treated barns, although a few of the flies appeared during the late fall about untreated barns.

A comparison of spray and vapor applications was made in two horse barns of approximately the same volume. Two spray treatments were required to maintain satisfactory control during the season. A total of 40 grams of actual lindane was used in these treatments. The lindane vapor application using a total of 61.73 grams during the season gave excellent control, the fly population never reaching above 10 flies per observation.

The results from spray treatment with methoxychlor, DDT and lindane in buildings and barns against flies are recorded in table 2.

Estimates of fly populations were obtained by observing favored areas where flies were known to rest. "Excellent" control represents only occasional flies, "Good control represents few flies, and "Fair" control, flies noticeable but seldom annoying to animals. In the diary barn 0.4 per cent lindane was applied only to such limited areas as doorways, stanchions, light fixtures, and overhead conveyor tracks, resulting in excellent control. However, the cows were treated weekly with a pyrethrum-piperonyl butoxide spray for horn flies which may have aided in keeping down the population (Bruce & Decker 1951). An isolated barn containing beef cattle, where flies became abundant, was treated late in the season with 2.5 per cent methoxychlor with good results. A 4 to 5 week residual effectiveness was evident with both methoxychlor and lindane (Hansens 1951). A 3 per cent DDT spray was used to treat the roosts and outside surfaces of the poultry plant, much of which was exposed to weather. Flies were noticeable but not numerous about the plant and fair control resulted.

SUMMARY.—The fly season of 1950 was an unusually long one, but the relative abundance of the flies was considerably less than during 1948 and 1949. Lindane vapor treatments gave somewhat better control in the barns than did lindane applied as a residual spray. Vaporized applications gave excellent control of houseflies in amounts of 1 gram or less per 20,000 cu. ft. per 24 hours. The volume of dispersed lindane necessary for effective control was dependent upon the relative air circulation. Nevertheless, effective fly control resulted in all barns with relatively small amounts of lindane. Vaporized lindane did not build up residual deposits as did spray applications with lindane, methoxychlor and DDT. Where cattle were retained in the barns and adjoining pens during the entire day, horn flies were eliminated by the vapor treatments. No deleterious effects from the continuous application of lindane vapor were evident.

No apparent resistance of flies to any of these insecticides was noticed throughout the experiment.

LITERATURE CITED

Bishopp, F. C. and L. S. Henderson. 1950. Housefly Control. U.S.D.A. Leaflet **182:** 1–8.

Bruce, W. W. and G. C. Decker. 1951. Control of horse flies on cattle. Ill. Nat. Hist. Survey, Biol. Notes **24:** 1–8.

Fulton, R. A., R. H. Nelson and F. F. Smith. 1950. The toxicity of Lindane vapor to insects. JOUR. ECON. ENT. **43**(2): 223–4.

Hansens, Elton J. 1951. Recent developments in the control of insect and parasitic pests. Amer. Vet. Med. Jour. **118,** 886: 38–41.

Effect on House Flies of Intermittent Exposures to Small Amounts of DDT Residues

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The mortality and knock-down of nonresistant and insecticide-resistant house flies, *Musca domestica* L., exposed intermittently to small amounts of DDT residues have been studied at the Corvallis, Ore., laboratory of the Bureau of Entomology and Plant Quarantine. The purpose of these studies was to determine if or to what extent the house fly has the ability to "detoxify" DDT when subjected to DDT intermittently with varying intervals of time between exposures.

MORTALITY EXPERIMENTS.—Female house flies, selected at random from a laboratory-reared nonresistant strain of flies, were exposed in glass fruit jars the interior of which had been treated with sufficient acetone solution of DDT to give a residue of 0.2 mg. of DDT per square foot. The treatments for these were as follows:

(1) Six 10-minute exposures at intervals of 1 hour in one 8-hour day.
(2) Four 10-minute exposures one day and two the following day with intervals of 1 hour and 45 minutes between exposures, except for a 16-hour interval between the exposures on the first and second days.
(3) Two 10-minute exposures on 3 successive days with approximately 7 hours between exposures on each day and approximately 16 hours interval between exposures on the different days.

The jars were retreated prior to each exposure period. Four replications were made of each treatment and from 20 to 30 flies were used in each replicate. In all treatments the flies were in contact with DDT residues for the same period of time (1 hour) but the average period of time between exposures varied.

A similar procedure was followed with the seventy-seventh and seventy-eighth generations of a colony of DDT-resistant flies developed at the Orlando, Fla., laboratory, except that the exposure periods were 20 minutes, the residue contained 0.5 mg. of DDT per square foot, and there were only two replications of each treatment.

Table 1 presents the results for both colonies of flies. Of the nonresistant flies the mortality was highest for the flies having the shortest interval between exposures (Treatment 1) and lowest for the flies having the longest interval between exposures (Treatment 3). The mortality of resistant flies was also greater for the flies exposed to the DDT at hourly intervals than for those exposed at intervals of 7 to 16 hours. There was no difference, however, between flies exposed at 1-hour intervals on 1 day (Treatment 1) and those exposed at intervals of 1 hour and 45 minutes on two successive days (Treatment 2). These tests suggest that nonresistant as well as resistant flies are capable of "detoxifying" or otherwise reducing the effect of DDT, provided there are several hours between exposures. Sternburg, *et al.* (1950) showed by chemical analysis that susceptible flies do not metabolize DDT but that resistant flies do. The present test indicated, however, that detoxification is a relatively slow process.

Survivors of the nonresistant flies given six exposures during a 3-day period (Treatment 3) were exposed for 40 or 60 minutes on the fourth day to a residue of 0.5 mg. of DDT per square foot. Four lots consisting of 12 to 28 flies per lot were tested and untreated groups of flies

Table 1.—Per cent mortality of house flies 20 hours after intermittent exposures to DDT.

Treatment	Exposures per Day	Nonresistant Colony (10-minute exposures to 0.2 mg. per sq. ft.)			Resistant Colony (20-minute exposures to 0.5 mg. per sq. ft.)		
		Two	Four	Six	Two	Four	Six
1	6	—	—	87	—	—	30
2	4	—	46	61	—	27	30
3	2	0	19	37	11	13	17

Table 2.—**Mortality of house flies surviving previous exposure to DDT (Treatment 3) and of previously untreated flies after further exposure to DDT residues.**

DDT Residue (mg. per sq. ft.)	Lot of Flies	Per Cent of Flies Surviving Treatment 3	Time of Further Exposure	Mortality After 24 Hours	
				Survivors of Treatment 3	Previously Untreated Flies
		Nonresistant colony			
0.5	1	41	40	100%	30%
	2	63	40	100	13
	3	54	40	77	28
	4	93	60	46	12
		Resistant colony			
5	5	83	180	70	20

were similarly exposed for comparison. Similar tests were made on one lot of flies from the resistant colony exposed for 180 minutes to 5 mg. of DDT per square foot. Table 2 shows the results of these tests.

The mortality of the previously treated flies was three to six times as high as that of the untreated flies. It seems probable that the flies were unable to tolerate the added exposure because of stored unmetabolized DDT or a toxic byproduct. In other experiments Lindquist *et al.* (1951) have shown by bioassay that DDT is apparently present in both nonresistant and resistant flies 24 hours after treatment. Sternburg, Kearns, and Bruce (1950) demonstrated by chemical analysis that resistant house flies contained DDT up to 57 hours after treatment. Perry and Hoskins (1950) obtained similar results.

Knock-down Experiments.—In efforts to gain additional information on the ability of the flies to overcome the toxic effects of intermittent exposure to DDT residual deposits, further tests were conducted in which the knock-down of nonresistant flies was studied. Female flies were exposed to residues of 0.3 or 0.4 mg. of DDT per square foot and then removed to a clean holding cage. The time required to knock down 50, 80, and 100 per cent of the flies was obtained, but only the results for 80 per cent knockdown are presented. Since the results with both residues were similar, the data have been combined. To complete the intermittent exposures within the life span of the house fly, it was necessary to increase the exposure period as the interval between exposures increased. This period was determined by the degree to which the flies were affected by the treatment and therefore varied from day to day. When the interval between exposures was 2 hours, only four exposures could be given in an 8-hour day, but they were continued the next day. Similar adjustments were necessary for the exposures at intervals of 3 and 4 hours.

Table 3 shows that when 24 hours intervened between exposures the total time required to knock down 80 per cent of the flies averaged 202 minutes as compared with 42 minutes when the interval was 1 hour. The knock-down times were intermediate between these extremes when flies were exposed to DDT at intervals of 2, 3, and 4 hours. These results confirm those of the mortality tests in demonstrating that nonresistant flies are able to reduce the effects of the poison when long periods intervene between exposures.

Mortality Studies with Radioactive DDT.—A series of tests were conducted in which resistant flies from the Orlando colony were exposed to residues of radioactive DDT (containing C^{14}). Intermittent and continuous exposures to 5 mg. per square foot were made and the surviving flies subjected to an additional long exposure. Following each exposure period, either intermittent or continuous, some live and all dead flies were removed for radioactivity counting. The flies were

Table 3.—**Total time required for 80 per cent knockdown of nonresistant house flies exposed intermittently to DDT residues. Average of tests with 0.3 and 0.4 mg. of DDT.**

Hours Between Exposures	Number of Exposures	Total Exposure (Minutes)
1	4	42
2	7	98
3	6	108
4	5.5	145
24	6	202

Table 4.—Radioactivity of resistant house flies after intermittent and continuous exposures to 5 mg. of radioactive DDT per square foot.

Exposure	Per Cent Mortality After 24 Hours	Counts per Minute for Groups of 9 Flies			
		Extract of Flies		External Wash	
		Survivors	Dead	Survivors	Dead
(1) Six intermittent 70-minute exposures	16	18	26	1	4
(2) Survivors of (1) with additional continuous 11-hour exposure	45	23	37	10	17
(3) One continuous 7-hour exposure	45	16	24	4	8
(4) Survivors of (3) with additional continuous 11-hour exposure	25	22	31	1	9

washed in acetone for about 30 seconds to remove exterior DDT, and then macerated in acetone to extract the absorbed radioactive materials. The amount of radioactivity was determined with a Geiger counter.

The radioactivity of the flies in each exposure group is shown in table 4. The counts for flies succumbing to a given treatment were always greater than counts for survivors. No significant differences in counts were demonstrated between flies exposed intermittently or continuously when the total exposure time was 7 hours. The mortality, however, was 45 per cent for the flies given continuous and only 16 per cent for those given intermittent exposures. This difference indicates that, even though nearly the same amount of radioactive DDT was absorbed by the two groups, a higher survival occurred with those flies allowed rest periods between exposures.

Similar data were obtained for flies given an additional continuous 11-hour exposure after surviving either continuous or intermittent treatment. It appears that, even though larger amounts of the DDT were absorbed, the mortality was not increased.

SUMMARY.—Studies have been conducted to determine the mortality and knock-down of house flies, *Musca domestica* L., exposed intermittently to small amounts of DDT residues.

Two 10-minute exposures at 7-hour intervals each day for 3 days to 0.2 mg. of DDT per square foot caused 37 per cent mortality of nonresistant flies, whereas six 10-minute exposures in 1 day killed 87 per cent. A similar mortality trend was obtained with resistant flies, but the differences between treatments were not so pronounced as with nonresistant flies. Since the mortality decreased as the time between exposures was lengthened, it is believed that the flies were able to detoxify themselves or otherwise reduce the effect of the poison.

Flies that survived the twice-a-day exposure were killed much more easily than untreated flies when subsequently exposed to a higher dosage of DDT. These results indicate that DDT or a toxic byproduct accumulates in the flies.

Knock-down tests with nonresistant flies showed that the total exposure time required to effect knock-down also increased as the time interval between exposures was lengthened.

In a series of tests with radioactive DDT resistant flies exposed intermittently for a total of 7 hours had an average reading of 18.3 cpm (counts per minute) with a 16 per cent mortality, whereas the flies exposed continuously for the same period had a reading of 16.3 cpm and a mortality of 45 per cent. Survival was therefore higher among the flies allowed rest periods between exposures, although the total amounts of DDT absorbed were similar in both lots.

LITERATURE CITED

Perry, A. S., and W. M. Hoskins. 1950. The detoxification of DDT by resistant houseflies and inhibition of this process by piperonyl cyclonene. Science **111**(2892): 600–1.

Sternburg, James, C. W. Kearns, and W. N. Bruce. 1950. Absorption and metabolism of DDT by resistant and susceptible house flies. JOUR. ECON. ENT. **43**(2): 214–9.

Lindquist, Arthur W., A. R. Roth, W. W. Yates, Robert A. Hoffman, and Joseph S. Butts. 1951. Use of radioactive tracers in studies of penetration and metabolism of DDT in house flies. JOUR. ECON. ENT. (In press).

Criteria for Evaluating Insecticidal Phytotoxicity—Aerial Growth[1]

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The need for reliable and rapid methods for estimating biological activity of insecticidal materials is generally recognized. For most of the more important pests, methods for measuring insecticidal effectiveness of chemicals are quite well established. Since the development of the many synthetic organic insecticides, however, a standard laboratory screening technique for measurement of relative phytotoxicity appears desirable.

Present methods employed for estimating insecticidal phytotoxicity are based largely on gross detection of damage to plants grown under field or greenhouse conditions. The laboratory procedure described in this paper is rapid and quantitative, and in many respects parallels certain methods used to identify plant auxins or hormones (Schneider 1938). Consideration of the possible development of these methods for measurement of insecticidal phytostimulation as well as phytotoxicity followed evidence by Chapman & Allen (1948), Goldsworthy (1948), Cullinan (1949), and others that organic insecticides may stimulate plant growth.

In developing a method for evaluating the relative phytotoxicity of insecticides, various techniques employed in detecting plant auxins or hormones were first tested. The Avena coleoptile test and an adaptation of the slit pea stem test (Went & Thimann 1937), using the pole bean or cucumber, proved usable, but did not distinguish between phytotoxicity and growth stimulation. The growth of cucumber roots in toxicant solutions was used to a large extent because of its sensitivity, but interpretation of results was difficult since root inhibition occurred at insecticidal concentrations that were found stimulating to aerial growth. Respiration and permeability studies, which showed that various compounds differed in their mode of action, were discarded as general criteria for phytotoxicity studies. The procedure which appeared most readily interpretable and which was satisfactory in giving consistent results employs the linear growth of bean[3] stem sections grown under standardized conditions in a nutrient solution.

Procedure.—A concise summary of the method for testing the effect of toxicants on the growth of isolated bean stem sections has been previously reported (Casida & Allen 1951). No details were given, however, regarding variations in technique or the adaptations of this procedure for evaluating insecticidal materials.

The procedure utilizes bean seedlings grown in the absence of light. Etiolated seedlings which range in height from 10 to 20 centimeters are selected for testing purposes. From each stem a 20.0 mm. section is removed—measured from a point 1 centimeter below the node at which the cotyledons are attached. After a sufficient number of sections are obtained they are placed in petri dishes with the toxicant, glass wool, and nutrient solution. Duplicate dishes, each with 10 sections, are used for each treatment. After 36 hours of growth, the sections are measured and comparisons are made with the standards, arsenic trioxide and 2,4-dichlorophenoxyacetic acid, on the basis of the phytotoxic index (the per cent inhibition of growth due to the toxicant).

Constituents of the nutrient solution are 1 per cent sucrose, indole-3-acetic acid at a concentration of 0.5 mg./L. and a M/40 phosphate buffer at pH 6.0. The auxin is added to supply a known and reproducible amount of plant growth substance to the stem sections. To prevent production of growth substances by the tissues, plant growth and all manipulations in the procedure take place in the dark or in subdued red light. Indole-3-acetic acid was selected as the source of auxin supply since it is readily available and occurs naturally in many plants. The suboptimal concentration employed al-

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[2] The authors are indebted to the Wisconsin Alumni Research Foundation for preparing and providing the organic acids used; and to Geigy Co., Inc.; Dow Chemical Co.; E. I. duPont de Nemours and Co., Inc.; Commercial Solvents Corporation; Julius Hyman and Co.; and to the Rohm and Haas Company for insecticide samples supplied.

[3] Kentucky Wonder Pole bean.

lows the maximum expression of plant response to the insecticide.

The pH of the solution is critical. A M/40 phosphate buffer at pH 6.0 appears most suitable. Since acidity increases the growth by increasing the fraction of the auxin in the undissociated form (Bonner, 1934), the solution was adjusted to a hydrogen ion concentration of 6.0. Certain insecticides such as the organic phosphates may alter the hydrogen ion concentration by hydrolysis or degradation, and special precautions must be taken where such compounds are used.

The test period is determined by the time taken for the cessation of elongation of the stem sections, which is approximately 30 hours. Measurements may be taken at the convenience of the worker after this growth period if no contamination is encountered. Contamination of cultures by microorganisms is reduced without apparent deleterious effect on the sections by adding one drop of toluene to each dish at the time the plant sections are introduced.

For testing small amounts of material, 5 ml. of the toxicant solution in a 50 ml. beaker may be employed. Under such conditions the sections are placed in an upright position along the inside periphery of the beaker. Capillarity holds the stem sections in an upright position and allows a more uniform exposure to the toxicant.

Further indication of stem section response may be based on criteria other than elongation of the section. The curvature of the sections, which generally occurs by the procedure described, indicates that a greater growth has occurred on one side of the stem. This response usually appears on that portion of stem surface in direct contact with the nutrient. Root induction and change in color or rigidity of the section during growth often occur, but special adjustment of conditions appears desirable if these criteria are to be employed for differentiation of responses.

The insecticide or toxicant may be applied by various means. A suspension of the insecticide in the nutrient solution can be prepared by using acetone or alcohol as a preliminary solvent, or a suspension of a wettable powder or an emulsion may be used. Dusts or sprays may be applied directly to the sections in the petri dishes. It was found that any standard apparatus for application of insecticides in treating caged insects may be used to treat the plant tissue. Sections may be exposed to the insecticide either separately or in the petri dish containing the nutrient solution.

Results.—The effect of certain insecticides on the bean stem section growth was studied under a number of conditions. In a test utilizing the standard procedure as described, the insecticide was applied as the purified chemical or as the wettable powder directly to the surface of the section at 10 mg. per section. A comparison of the action of these insecticides with the standards in shown in figure 1 and table 1. Analysis of variance showed the least significant difference in the phytotoxic indexes to be 18.5 for the 5 per cent level of probability and 24.2 for the 1 per cent level.

The response to technical DDT with two different methods of application in various unbuffered nutrients is shown in table 2. It is evident that omission of certain of the nutrient solution constituents will cause a change in the plant section response to the insecticide.

The adaptability of this method for studies of the relation of structure to activ-

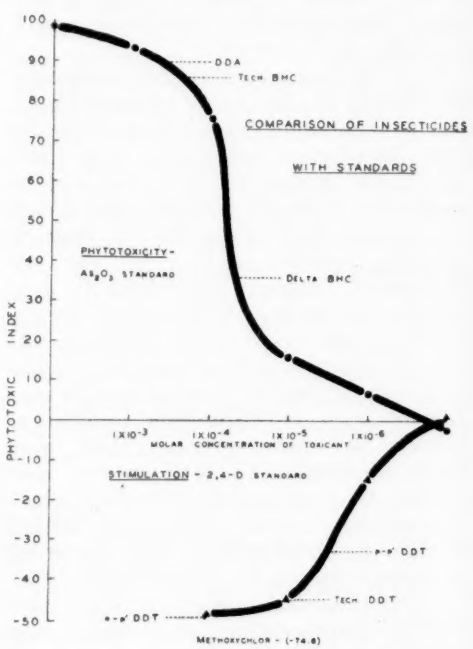

FIG. 1.—Effect of insecticidal dusts on bean stem section growth.

Table 1.—**Effect of insecticidal dusts applied directly to the stem sections of Kentucky Wonder Pole Bean.**

INSECTICIDE NAME	PHYTOTOXIC INDEX	COMPARABLE TO STANDARD
I—DDT analogs		
Technical DDT (s. p. 89°)	−45	1.0×10^{-5}M. 2,4-D
2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane	−34	3.2×10^{-6}M. 2,4-D
2-(o-chlorophenyl)-2-(p-chlorophenyl)-1,1,1-trichloroethane	−50	1.0×10^{-4}M. 2,4-D
4,4′-dichlorodiphenylacetic acid	90	5.1×10^{-4}M. As_2O_3
2,2-bis-(p-chlorophenyl)-1,1-dichloroethylene	−47	1.6×10^{-5}M. 2,4-D
2,2-bis-(p-methoxyphenyl)-1,1,1-trichloroethane	−75	>2,4-D
2,2-bis-(p-chlorophenyl)-1,1-dichloroethane	−49	1.0×10^{-4}M. 2,4-D
2-nitro-1,1-bis-(p-chlorophenyl)-propane	−32	3.2×10^{-6}M. 2,4-D
2-nitro-1,1-bis-(p-chlorophenyl)-butane	−29	5.0×10^{-6}M. 2,4-D
2,2-bis-(p-ethylphenyl)-1,1-dichloroethane	−25	1.6×10^{-6}M. 2,4-D
2,2-bis-(phenyl)-1,1,1-trichloroethane	−14	7.9×10^{-7}M. 2,4-D
II—Benzene hexachloride derivatives		
Technical BHC (12% gamma)	86	2.5×10^{-4}M. As_2O_3
95% gamma BHC	−43	7.9×10^{-6}M. 2,4-D
alpha isomer BHC	−47	1.6×10^{-5}M. 2,4-D
beta isomer BHC	−33	3.2×10^{-6}M. 2,4-D
gamma isomer BHC	−52	>2,4-D
delta isomer BHC	36	4.5×10^{-5}M. As_2O_3
III—Other chlorinated hydrocarbons		
Aldrin	−39	6.3×10^{-6}M. 2,4-D
Dieldrin	−37	4.5×10^{-6}M. 2,4-D
Heptachlor	−21	1.4×10^{-6}M. 2,4-D
IV—Wettable powders and others		
Chlordane (50% W. P.)	34	4.0×10^{-6}M. As_2O_3
Toxaphene (40% W. P.)	9	2.2×10^{-6}M. As_2O_3
DDT (50% W. P.)	5	7.1×10^{-7}M. As_2O_3
Talc	−15	1.0×10^{-6}M. 2,4-D
Rotenone (Rotenone. CCl_4 crystals)	5	7.1×10^{-7}M. As_2O_3
L.S.D. .01	24.2	
.05	18.5	

ity is shown in table 3. These data are a result of a study of compounds related to 4,4′-dichlorodiphenylacetic acid, a degradation product of DDT and a metabolite of DDT in rabbits (White & Sweeney 1945).

DISCUSSION.—The stimulation of plant growth by certain of the chlorinated hydrocarbons has been frequently noted in greenhouse studies and field observations (Chapman & Allen 1948; Cullinan 1949; Simkover & Shenefelt 1951). Laboratory studies have also shown stimulation by DDT (Thompson *et al.* 1946; Fults & Payne, 1947). Concentration is an important factor for such studies as stimulation occurs within a limited range and inhibition at higher toxicant concentrations.

Several of the above authors have suggested an auxin-like activity for DDT. In the studies reported here, confirmation of this stimulation was obtained. Highly significant stimulation occurred with many of the compounds. Methoxychlor

Table 2.—**Effect of nutrient solution constituents on the phytotoxic index of technical DDT.**

NUTRIENT	METHOD OF APPLICATION: Dusted on sections (10 mg./section)	1×10^{-3} M susp. (in 2% alcohol)
H_2O	−18	−8
1% sucrose	−30	−35
Indole-3-acetic acid (0.5 mg./L.)	2	23
1% sucrose+0.5 mg./L. Indole-3-acetic acid	10	4

Table 3.—**Phytotoxic indices of some mono- and bisphenyl and phenoxy acetic acids at 1×10^{-3} M.**

R GROUP	MONO (RCH_2COOH)	BIS ($R_2CHCOOH$)
phenoxy	35	56
p-chlorophenoxy	−15	51
o-chlorophenoxy	6	63
2,4-dichlorophenoxy	46	72
2,4,5-trichlorophenoxy	70	98
phenyl	13	52
p-chlorophenyl	24	75

and gamma isomer benzene hexachloride caused a stimulation greater than was attained with 2, 4-D. The relative action of the benzene hexachloride derivatives is in agreement with reports in the literature where other methods were utilized. In certain cases a beneficial action of the insecticide to the plant, other than merely insect control, appears possible.

DDT stimulated plant growth in the unbuffered nutrient solution in which no auxin (indole-3-acetic acid) was present and inhibited growth when an auxin was present. This further indicates a relationship between DDT and auxins in the plant metabolism.

Structurally, DDT and 4,4′-dichlorodiphenylacetic acid are related to the known auxins. Except for the spatial relationships of the groups, DDT, and more especially 4,4′-dichlorodiphenylacetic acid, will superficially meet the structural requirements for auxin activity as suggested by Koepfli, *et al.* (1938).

The study of the toxicity of certain organic acids related to 4,4-′-dichlorodiphenylacetic acid, table 3, showed that the order of phytotoxic action is similar for the mono and bis derivatives. In all cases the toxicity of the bis compound is greater than the corresponding monophenyl or monophenoxy analog. Both the bis-phenyl and the bis-phenoxy compounds are highly toxic. As with the toxicity of DDT to insects, the phytotoxic action of these related organic acids as determined by the described procedure appears to be associated with the bis arrangement and is dependent on the substitutions present.

SUMMARY.—A standardized laboratory method for evaluating the mode of action of insecticides on plant aerial growth is reported. This procedure allows a rapid screening technique that can be used to test for both inhibitory or stimulatory effect of the insecticide.

The inhibitory action to stem section elongation of certain organic acids related to 4, 4′-dichlorodiphenylacetic acid appears to be enhanced with the "bis" structure and varies with ring substituents, a situation similar to that which governs the toxicity of DDT analogs to insects.

Further evidence of the stimulating action of certain insecticidal chlorinated hydrocarbons is given. A relationship of the affect of DDT to the auxin supply available to the plant is shown.

LITERATURE CITED

Bonner, J. 1934. The relation of hydrogen ions to the growth rate of the *Avena* coleoptile. Protoplasma **21**: 406–23.

Casida, J. E., and T. C. Allen. 1951. A laboratory method for evaluating the phytotoxicity or phytostimulation of insecticides. Science *113*(2941): 553–5.

Chapman, R. K. and T. C. Allen. 1948. Stimulation and suppression of some vegetable plants by DDT. JOUR. ECON. ENT. **41**(4): 616–23.

Cullinan, F. P. 1949. New insecticides. Their effect on plants and soils. JOUR. ECON. ENT. **42**: 387–91.

Fults, J. L. and M. G. Payne. 1947. A biometric evaluation of the growth-regulating and herbicidal properties of some organic compounds. Jour. Am. Soc. Agron. **39**: 667–81.

Goldsworthy, M. C. 1948. Effect of soil applications of various chlorinated hydrocarbons (insecticides) on the top growth of Blakemore strawberry plants. Plant Disease Reptr. **32**: 186–8.

Koepfli, J. B., K. V. Thimann and F. W. Went. 1938. Phytohormones: Structure and physiological activity. I. Jour. Biol. Chem. **122**: 763–80.

Schneider, C. L. 1938. The interdependence of auxin and sugar for growth. Am. Jour. Bot. **25**: 258–69.

Simkover, H. G. and R. D. Shenefelt. 1951. Phytotoxicity of some insecticides to coniferous seedlings with particular reference to benzene hexachloride. JOUR. ECON. ENT. In press.

Thompson, H. E., C. P. Swanson and A. G. Norman. 1946. New growth regulating compounds. I. Summary of growth-inhibitory activities of some organic compounds as determined by three tests. Bot. Gaz. **107**: 476–507.

Went, F. W. and K. V. Thimann. 1937. Phytohormones. N. Y. MacMillan.

White, W. C. and T. R. Sweeney. 1945. The metabolism of 2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane (DDT) I. U. S. Pub. Health Service, Pub. Health Repts. **60**(3): 66–71.

Criteria for Evaluating Insecticidal Phytotoxicity—Root Growth[1]

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A laboratory method has been recently reported for measurement of relative phytotoxicity and phytostimulation of insecticidal materials applied to the aerial portions of the plant (Casida & Allen, 1951 and Allen & Casida, 1951). Insecticidal treatment of soils for the control of subterranean insects may also cause plant damage (Goldsworthy 1948; Foster 1950; and others). In addition, it has been reported (Fults & Payne 1947) that DDT causes significant root stimulation. As root responses to chemicals of either stimulatory or inhibitory action differ from those expressed by plant aerial portions, a rapid laboratory method for evaluating the relative effects of insecticides on root growth has been given consideration by the authors.

Present methods for estimating the relative toxic action of insecticides to roots involve observations of the response of plants grown in the field, greenhouse, or in aseptic plant cultures under laboratory conditions (Audus & Quastel, 1947). The procedures, however, which have been employed for auxin assay (Bonner & Koepfli, 1939; Thompson *et al.* 1946; and others) would suggest possible adaptation for measuring the phytotoxic action of insecticides on roots. Such techniques are based on the ability of the chemical to inhibit root growth.

Chlorinated hydrocarbons are quite widely used for controlling soil inhabiting insects, and little information is available as to the effect of the insecticide on the roots of plants. The purpose of this paper is to describe a method for evaluating relative phytotoxicity of insecticides and their mode of action employing cucumber root growth as the criterion of differentiation. DDT and some related compounds are employed to illustrate the procedure and obtainable results.

Procedure.—Cucumber seeds[3] from a uniform standard lot are immersed in water for one hour and then germinated in the absence of light between moist paper towels or on moist filter paper within covered petri dishes. After a 24-hour germination period, seeds in which the roots are from 1 to 2 mm. in length are selected for testing. Careful selection of seed is necessary in order to help insure consistent results. The growth of the plants and any necessary manipulation of the seeds take place in the dark or in the presence of red light of low-intensity.

The germinated seeds are then transferred to petri dishes containing 5 ml. of the toxicant solution. A filter paper, 9 cm. in diameter, has been previously placed on the bottom of each petri dish to serve as a support for the seeds and for absorbing the excess solution. The solution contains M/40 phosphate buffer ($K_2HPO_4 + KH_2PO_4$) at pH 5.0. The pH is critical since it affects the activity of the chlorinated hydrocarbons. This buffer combination was found to be the least toxic to plant tissue among those tested.

Suspensions are prepared for toxicants that are insoluble in water. The toxicants are dissolved in acetone, water added rapidly with mixing, and then the acetone is evaporated off at room temperature. Although alcohol solutions yielded finer suspensions, alcohol was unsatisfactory due to its toxicity and lower solvent action for the chemicals tested.

Two petri dishes each containing 10 seeds were usually employed as the test sample for each dilution. For the detection of small differences, three dishes with 15 plants each were used. The seeds were then incubated in the absence of light for a period of 36 hours at room temperature. The entire series of seedlings must be subjected to identical periods of growth. Following completion of the 36-hour incubation, the petri dishes are held at a temperature of 4° C. for a period of at least 1 to 2 hours. This chilling slows up the growth so that the seedlings can then be evaluated at the convenience of the

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[3] Chicago Pickling Variety.

worker. Checks of the buffer solution and of the solvent concentrations are included in the treatment series.

The evaluation of toxic action is based on both inhibition of growth in length and weight. A single criterion did not suffice as club formation, a behavior characteristic of certain auxins, or development of excessive cell elongation leads to erroneous conclusions. Root lengths are measured in millimeters from the point of attachment of the cotyledons to the root tip. The weights are based on the wet weight of the roots when cut off at the cotyledons.

In all determinations of relative activity of chemical agents, arsenic trioxide (As_2O_3) and 2,4-dichlorophenoxyacetic acid (2,4-D) are included as standards in the test series. Comparisons of results are conveniently made by using the phytotoxic index (the per cent inhibition of growth due to the toxicant) as previously reported by Casida & Allen, 1951. The relative activity of 4,4′-dichlorodiphenylacetic acid, 2,4-D, and As_2O_3 by the above method is shown in figure 1. The various steps in the method are illustrated in figure 2.

RESULTS.—The adaptability of this method is demonstrated by studies of the phytotoxic action of DDT and certain related compounds.

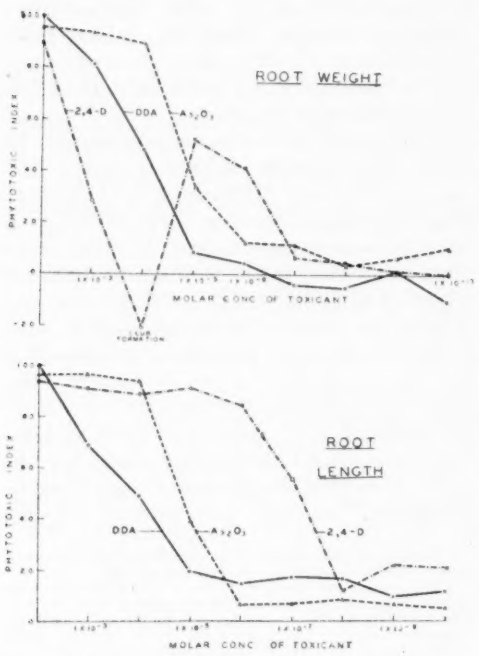

FIG. 1.—Relative toxicity of 4,4′-dichlorodiphenylacetic acid (DDA) and the standards 2,4-D and As_2O_3 to cucumber root growth.

Suspensions of the more important DDT analogs were tested for their effect on cucumber root growth. Those compounds listed in table 1 possess a phytotoxic index of less than 20 for concentrations of 1×10^{-2}, 1×10^{-3}, and 1×10^{-4} M. Those compounds in table 2 showed a higher toxic action. Of the impurities known to be present in the technical grade of DDT, only 2-(p-chlorophenyl)-1,1,1-trichloroethanol was highly toxic. The next most inhibitory impurity of DDT was bis-(p-chlorophenyl)-sulphone which showed a 17 per cent inhibition of growth in root length and weight at 1×10^{-2} M. The o-p′ isomer of DDT was more toxic than the technical grade DDT, which in turn was more toxic than the p-p′ isomer. The o-o′ isomer of DDT was inactive. Of the DDT degradation products, 4,4′-dichlorodiphenylacetic acid was the most toxic, although 4,4′-dichlorobenzophenone inhibited 19 per cent at 1×10^{-2} M. Those compounds that caused stimulation of root elongation at the lower concentrations were 2,2-bis-(p-chlorophenyl)-ethane, 4,4′-dichlorodiphenylmethane, 4,4′-dichlorobenzophenone, and 4,4′-dichlorostilbene. Of the insecticidally important analogs, methoxychlor was the most active. It caused a slight club formation. The compound 2,2-bis-(phenyl)-1,1,1-trichloroethane was also active.

The high toxicity of 4,4′-dichlorodiphenylacetic acid (DDA), figure 1 and table 2, compared with compounds of recognized auxin activity has been previously reported (Allen & Casida, 1951). Results, table 3, show that p-chlorophenyl acetic acid is slightly less toxic than its bis-(p-chlorophenyl) analog, 4,4′-dichlorodiphenylacetic acid while the activity of p-chlorophenoxy acetic acid is largely lost by the "bis" compound.

The hydrogen ion concentration of the solution has a pronounced effect on the inhibitory action of DDT. The hydrogen ion concentration of the solution did not significantly alter the growth of the plant in the range of pH 4.0 to 10.0. With the phosphate buffer, however, pH change of the buffer ($K_2HPO_4+KH_2PO_4$) distinctly altered the plant growth due to change in the potassium/phosphorus balance in the solution. Experimental con-

trols for pH studies were adjusted with M/100 sodium hydroxide and hydrochloric acid and with the buffer solutions. In studies of the activity of DDT at different hydrogen ion concentrations, it was found that the minimum toxicity of the technical compound occurred between pH 6.0 and 7.0. The nature of the action of the insecticide, whether stimulatory or inhibitory depended on the concentration present in the particular experiment. In one trial utilizing 1×10^{-3} M.

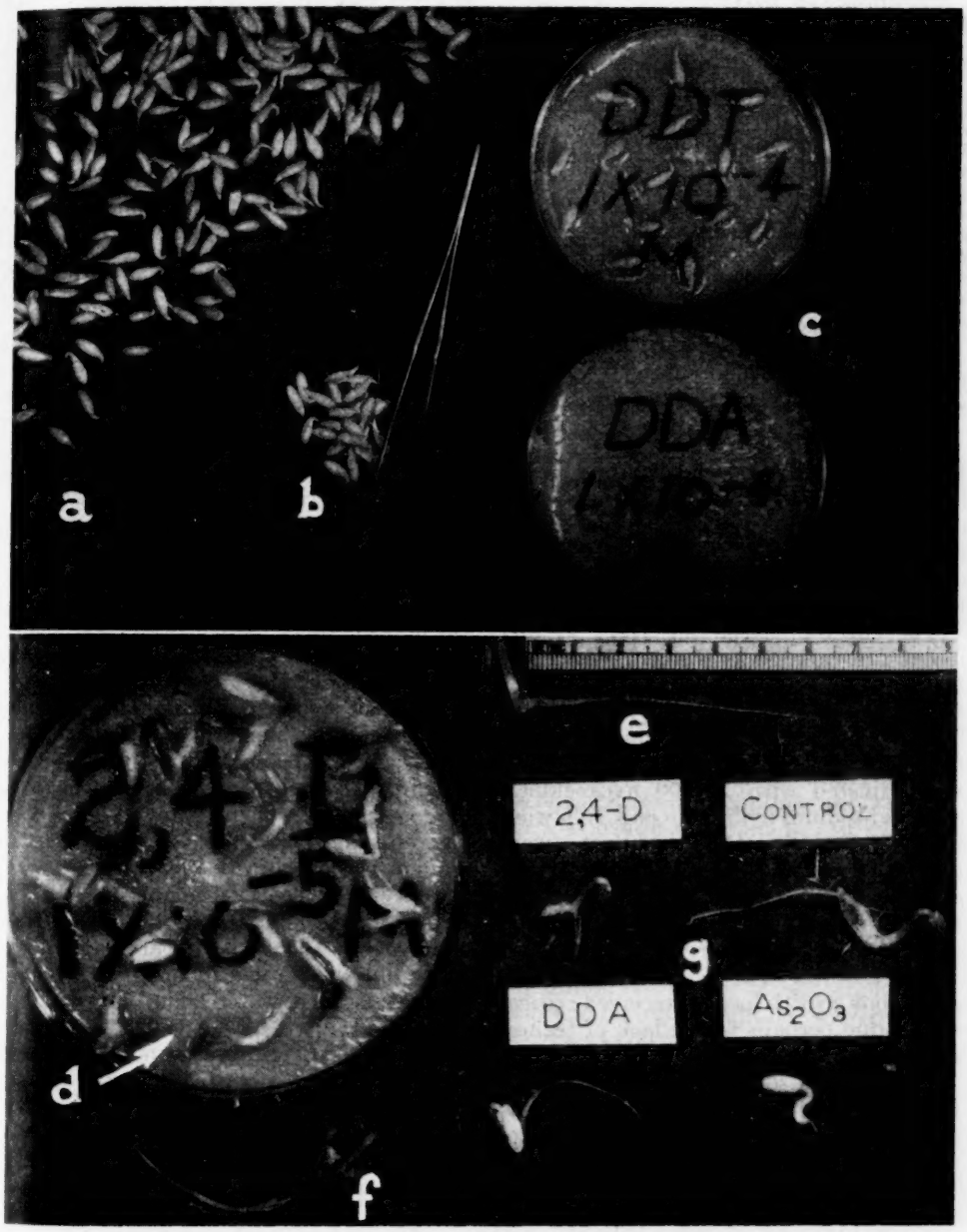

FIG. 2.—Method employed for determination of inhibitory action of toxicants to cucumber root growth. From a uniform lot of germinated seeds (A) a sufficient number of seeds (B) are selected and placed in petri dishes (C) with toxicant for subsequent growth. After 36 hours the roots (D) are measured (E) and the wet weight of the roots (F) is determined. The action of DDA, 2,4-D, and As_2O_3 at 1×10^{-5} M. is illustrated (G). (Note the club formation with 2,4-D.)

Table 1.—Compounds with phytotoxic index less than 20 for root elongation and weight gain at concentrations of 1×10^{-2}, 1×10^{-3} and 1×10^{-4} molar.

Technical DDT. (setting point 89°)
2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane (p-p′ DDT)
2-(o-chlorophenyl)-2-(p-chlorophenyl)-1,1,1-trichloroethane (o-p′ DDT)
2,2-bis-(o-chlorophenyl)-1,1,1-trichloroethane (o-o′ DDT)
2,2-bis-(p-chlorophenyl)-1,1-dichloroethane (p-p′ DDD)
bis-(p-chlorophenyl)8sulphone
2,2-bis-(p-chlorophenyl)-1,1-dichloroethylene
2,2-bis-(p-chlorophenyl)-ethane
4,4′-dichloro-diphenylmethane
4,4′-dichlorobenzophenone
4,4′—dichlorostilbene
2,2-bis-(p-methylphenyl)-1,1,1-trichloroethane
2,2-bis-(p-ethylphenyl)-1,1-dichloroethane
2-nitro-1,1-bis-(p-chlorophenyl)-propane
2-nitro-1,1-bis-(p-chlorophenyl)butane
A commercial product (2 parts of 2-nitro-1,1 bis-(p-chlorophenyl)-butane 1 part of 2-nitro-1,1-bis-(p-chlorophenyl)-propane
DDT—liquid polymer

DDT in unbuffered solutions and a 24-hour growth period, there was inhibition of root elongation due to the insecticide in the pH range of 2.0 to 6.0. On the other hand, stimulation occurred within the range of pH 7.0 to 11.0.

The effect of extracting DDT at different pH values was studied. Water extracts were prepared from 5 grams of technical DDT at pH 3.0, 7.0, and 11.0 by exposing DDT suspensions to water for 24 hours. The pH for the extraction was adjusted with M/100 hydrochloric acid and sodium hydroxide and, following filtering off of the DDT,[1] the filtrates were adjusted to pH 5.0 for the growth of the cucumber roots. An increasing toxicity of the extract with increasing hydrogen ion concentration was observed.

DISCUSSION.—The effect of DDT on plant root growth has not received critical study, due perhaps to the lack of techniques to aid in its evaluation.

The effect of soil reaction on toxicity of DDT was studied by Cullinan (1947) who noted that when lime was added so as to raise the hydrogen ion concentration the toxicity of DDT was increased. Due to variation in soil type and capacity for surface absorption in different soils, control of conditions in field studies is difficult. Controlled laboratory studies reported in this paper indicate that the toxicity of DDT to cucumber root growth is least near neutrality, and that a filterable toxic component (or components) can be leached with dilute acid. The change in the activity of DDT with pH may be due to various factors, among which are degradation, solubility, ionization or change in plant response with pH.

Of the impurities present in the technical grade DDT, only 2-(p-chlorophenyl)-1,1,1-trichloroethanol showed a high toxic action. This compound appears in the technical grade of DDT to the extent of 0.2 per cent (Haller *et al.* 1945), to 1.5 per cent (Mosher *et al.* 1946) or as high as 3.2 per cent if other half condensation products are also considered (Forrest *et al.* 1946). It appears as a half condensation product of chloral and chlorobenzene, is the most volatile of the commonly occurring impurities of DDT and is readily soluble in organic solvents. Observations by the authors indicate that this compound has the highest water solubility of the DDT impurities considered in this study. The increased toxicity of the technical grade DDT over that of the aerosol grade has been noted by numerous authors (Carruth & Hervey 1947 and others). This might be explained by the removal of this toxic ethanol in purification to form the aerosol grade. Alban & Keirns (1948) noted that when DDT was separated into four fractions, the most toxic was the sludgy oil portion: 2-(p-chlorophenyl)-1,1,1-trichloroethanol should appear in this fraction. The possibility that the very small water soluble fraction of the insecticide is the cause of the plant damage was suggested by Crowell & Morrison (1950) from observation of increased DDT toxicity on wet foliage. Of the impurities present in the technical grade of DDT, this ethanol has the highest water solubility and would be present in the greatest concentration in a water solution from the technical compound. The volatility of this ethanol and its more rapid penetration in a gaseous state might explain the observation of Magie (1947) that the toxicity of DDT to gladiolus occurs on warm sunny days. It appears, therefore, that 2-(p-chlorophenyl)-1,1,1-trichloroethanol, the most toxic impurity of DDT to cucumber root growth, could explain the field observations of DDT toxicity made by numerous authors.

It is of interest to note that 2-(p-chloro-

Table 2.—Relative phytotoxicity of those analogs, impurities and degradation products of DDT with phytotoxic index greater than 20.

Compound	Phytotoxic Index					
	1×10^{-2} M.		1×10^{-3} M.		1×10^{-4} M.	
	lgth.	wgt.	lgth.	wgt.	lgth.	wgt.
2-(p-chlorophenyl)-1,1,1-trichloroethanol	100	80	98	74	45	37
4,4′-dichlorodiphenyl-acetic acid	88	91	85	90	76	71
2,2-bis-(p-methoxyphenyl)-1,1,1-trichloroethane	47	6	16	7	−10	19
2,2-bis-(phenyl)-1,1,1-trichloroethane	57	29	50	30	30	6
Standards						
2,4-D	90	91	87	54	87	31
As_2O_3	88	94	84	86	82	85

phenyl)-1,1,1-trichloroethanol was found by Lumsden & Smith (1948) to cause relatively little damage when applied as an emulsion to Kalanchoe. Such observations were based on gross injury of the plant due to this ethanol. On the other hand an inhibitory action of this chemical on cucumber germination was indicated by Hopkins & Toole (1950). The toxicity of bis-(p-chlorophenyl)-sulphone has been observed previously (Cullinan 1947).

Another possibility of the toxic action of DDT involves the degradation to the highly phytotoxic 4,4′-dichlorodiphenyl-acetic acid (DDA). This compound appears as a metabolite of DDT in rabbits (White & Sweeney, 1945) and might possibly be formed as a result of the plant metabolizing DDT. The slow or delayed effect of DDT in certain cases where continued applications are made over an extended period of time, suggests that the toxic action may be due to metabolism.

Previous consideration has been made (Allen & Casida, 1951) of the similarity of 4,4′-dichlorodiphenylacetic acid (DDA) to auxins in general activity and structure. From available information it appears that this compound is less inhibitory, in comparison with 2,4-D, to cucumber root elongation than to bean stem elongation. It is characteristic of known auxins to be more inhibitory to root elongation than to stem elongation. In addition, the lack of clubbing noted with 4,4′-dichlorodiphenylacetic acid and the formation with the auxins tested would suggest that this compound does not act primarily on growth as known auxins do.

Table 3.—Relative phytotoxic action of the mono- and diphenyl and phenoxy acetic acids with para substituted chlorine.

Compound	Concentration of P.I. 50		Notes
	Weight	Length	
	(M)	(M)	
p-chlorophenyl acetic acid	8.0×10^{-4}	2.7×10^{-3}	partial club
bis(p-chlorophenyl) acetic acid	7.1×10^{-5}	7.1×10^{-5}	no club
p-chlorophenoxy acetic acid	1.0×10^{-5}	$<1\times10^{-6}$	club
bis(p-chlorophenoxy) acetic acid	$>1\times10^{-3}$	$>1\times10^{-3}$	no club
2,4-dichlorophenoxy acetic acid	3.5×10^{-6}	$<1\times10^{-6}$	club
arsenic trioxide	1.8×10^{-5}	1.6×10^{-5}	no club

Further consideration was given to the mode of action of DDA. It was found that leaf tip cells of *Elodea*, which were plasmolyzed in 0.5 M. sodium chloride solution, recovered their turgidity in 2 minutes when transferred to distilled water, but failed to recover if 4,4′-dichlorodiphenyl-acetic acid was present in the salt solution at a concentration of 5×10^{-3} M. These results suggest activity due to effect on membrane permeability. The oxygen uptake of leaf discs of cucumber, as observed with a Warburg respirometer, utilizing a pH 5.0, M/20 phosphate buffer, was inhibited 86 per cent (per cent inhibition based on ul. O_2 uptake/gm. fresh wt./hr.) when 4,4′dichlorodiphenylacetic acid was present at a concentration of 1×10^{-3} M. This inhibitory action of 4,4′-diphenyl-acetic acid on oxygen uptake was irreversible. The known auxins at high concentration normally cause the respiratory rate to decline over a long period of time but do not produce the abrupt inhibitory effect observed here. However, certain materials that act by affecting membrane permeability are known to cause such sharp respiratory inhibition. DDT at the same concentrations caused no appreciable effect on oxygen uptake at pH 5.0 with cucumber leaf discs nor did it at pH 7.0 with cucumber or *Kalanchoe* leaf

sections. From the above considerations it would appear that 4,4′-dichlorodiphenylacetic acid inhibits primarily by affecting the membrane permeability.

SUMMARY.—A standardized procedure has been described for evaluating relative root growth responses to DDT and related compounds. Phytostimulatory as well as phytotoxic actions were measurable utilizing growth responses of cucumber roots when subjected to minute amounts of various toxicants in petri dishes. DDT and related compounds were used in a series of tests to demonstrate attainable results.

Further evidence as to the mode of phytotoxic action of DDT is presented. Of the impurities known to exist in technical DDT, the inhibitory action of 2-(p-chlorophenyl)-1,1,1-trichloroethanol helps explain field observations of DDT toxicity by numerous authors. The toxic action of DDT might be associated with the possible breakdown to 4,4′-dichlorodiphenylacetic acid, which appears to act by affecting the membrane permeability rather than by an auxin-like effect. Methoxychlor was the most inhibitory of the commonly used analogs of DDT tested. The hydrogen ion concentration is critical in determining the effect of DDT on root growth.

Root responses to chemicals differ from that following application of such materials to the above ground portions of the plant. The evaluation of toxicants should include both the effect on above ground portions, as in the bean stem section method, and on roots, as in the cucumber root growth method. The applicability of these methods is considered to be more general than the specific studies reported here.

LITERATURE CITED

Alban, E. K., and V. E. Keirns. 1948. The effect of rotenone, commercial and aerosol grade DDT dusts on the total yield, grade and maturity of seven cucurbit varieties. Proc. Amer. Soc. Hort. Sci. **51:** 448–52.

Allen, T. C., and J. E. Casida. 1951. Criteria for Evaluating Insecticidal Phytotoxicity—Aerial Growth. JOUR. ECON. ENT. **44**(5): 738–41.

Audus, L. J., and J. H. Quastel. 1947. Selective toxic action of thiosulfate on plants. Nature **160:** 263–4.

Bonner, J., and J. B. Koepfli. 1939. The inhibition of root growth by auxins. Am. Jour. Botany **26:** 557–66.

Carruth, L. A., and G. E. R. Hervey. 1947. DDT and other insecticides for squash borer control. JOUR. ECON. ENT. **40**(5): 716–21.

Casida, J. E., and T. C. Allen. 1951. A laboratory method for evaluating the phytotoxicity or phytostimulation of insecticides. Science **113**(2491): 553–5.

Crowell, H. H., and H. E. Morrison. 1950. The phytotoxicity to cucurbits of some new insecticides. JOUR. ECON. ENT. **43**(1): 14–6.

Cullinan, F. P. 1947. Effects of some of the newer organic chemicals on plant life. Agr. Chem. **2**(5): 18–20.

Forrest, J., O. Stephenson and W. A. Waters. 1946. Chemical investigations of the insecticide "DDT" and its analogues. Part I. Reactions of "DDT" and associated compounds. Jour. Chem. Soc. **1946:** 333–9.

Foster, A. C. 1950. How toxic to plants are some of the new insecticides? Agr. Chem. **5**(8): 37–8.

Fults, J. L., and M. G. Payne. 1947. Secondary root stimulation in the common bean *Phaseolus vulgaris* L., caused by the insecticides DDT and Colorado 9. Bull. Torrey Bot. Club. **74**(2): 112–4.

Goldsworthy, M. C. 1948. Effect of soil applications of various chlorinated hydrocarbons (insecticides) on the top growth of Blakemore strawberry plants. Plant Disease Rept. **32:** 186–8.

Haller, H. L. *et al.* 1945. The chemical composition of technical DDT. Jour. Amer. Chem. Soc. **67:** 1591–602.

Hopkins, H. T. and E. H. Toole. 1950. Effect of DDT on germination of certain seeds. Bot. Gaz. **112**(1): 130–2.

Lumsden, D. V., and F. F. Smith. 1948. Growth responses by kalanchoes to DDT and other synthetic compounds. Proc. Amer. Soc. Hort. Sci. **51:** 618–22.

Magie, R. O. 1947. DDT injuries gladiolus florets. Gladiolus Mag. **11**(6): 11–2.

Mosher, H. S., M. R. Cannon, E. A. Conroy, R. E. Van Strien and D. P. Spalding. 1946. Preparation of technical DDT. Ind. Eng. Chem. **38:** 916–23.

Thompson, H. E., C. P. Swanson and A. G. Norman. 1946. New growth regulating compounds. I. Summary of growth inhibitory activities of some organic compounds as determined by three tests. Bot. Gaz. **107:** 476–507.

White, W. C., and T. R. Sweeney. 1945. The metabolism of 2,2-bis-(p-chlorophenyl) 1,1,1-trichloroethane (DDT) I. U. S. Pub. Health Service, Pub. Health Repts. **60**(3): 66–71.

Two Systemic Insecticides for Control of the Pea Aphid

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Octamethyl pyrophosphoramide appeared to offer such promise as a systemic insecticide that preliminary tests with it were commenced at Madison, Wisconsin, in 1950 against the pea aphid, *Macrosiphum pisi* (Kltb.), infesting canning peas.

Schrader (1946), who first produced certain derivatives of *bis*(dimethylamino)-phosphoric anhydride, called attention to their ability to penetrate into the sap of plants and kill both sucking and leaf-eating insects. David & Kilby (1949) reported that *bis*(*bis*-dimethylamino)-phosphonous anhydride (octamethyl pyrophosphoramide) was translocated from the roots of potted bean plants to the leaves, where it killed the bean aphid, *Aphis fabae* Scop. Ripper *et al.* (1949) reported the anhydride as a selective insecticide capable of killing certain plant pests without destroying their enemies. Ripper *et al.* (1950) found that when sprayed on the foliage of plants the anhydride had no contact or fumigation effect against aphids. They found it toxic to 14 species of aphids and that most sprayed crops remained toxic to aphids for 3 to 4 weeks. David (1950) reported that radioactivity could be detected in the leaves a few hours after the roots of broad bean plants were placed in a culture solution containing radioactive anhydride, and shortly thereafter bean aphids on the leaves began to fall off. Ivy *et al.* (1950) reported that octamethyl pyrophosphoramide was effective against the cotton aphid, *Aphis gossypii* Glov., when applied to the cottonseed at planting time. In experiments by Smith *et al.* (1950) six species of aphids and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, were killed on the foliage of plants growing in soil that had been treated with octamethyl pyrophosphoramide.

Greenhouse Tests.—Preliminary tests were conducted in a greenhouse to determine the effect of octamethyl pyrophosphoramide against the pea aphid when the chemical was sprayed on the Perfection variety of canning pea plants, poured on soil in which plants were to be grown, or applied to the seed before it was planted. A material of approximately 90 per cent purity was used.

Chemical sprayed on plants.—Uninfested pea plants 4 inches tall, growing in No. 2 tin cans, were thoroughly wetted with spray at the strength of 1 gram of the chemical to 860 ml. of water (about 1 pound to 100 gallons). All plants showed foliage injury, which became progressively worse for several days after treatment. There was some chlorosis and many of the lower leaves dried up. New growth appeared, however, and the plants were manually infested with adult apterous aphids 13 days after the spraying. There was no mortality in 24 hours, but 50 per cent mortality in 48 hours and 100 per cent in 72 hours, with 20 per cent in the checks.

In another test plants were treated as before and similar foliage injury resulted. Adult aphids were placed on plants 3 days after the spraying, with 90 per cent mortality resulting in 24 hours and 100 per cent in 48 hours, but none in the checks.

Chemical poured on soil.—Octamethyl pyrophosphoramide was prepared at the three concentrations 0.2, 0.1, and 0.05 ml. in 30 ml. of water, and one concentration poured on top of the soil in each tin can just before the pea seed was planted. The two higher concentrations caused marked chlorosis and burning of the foliage, whereas the lowest concentration affected the foliage much less.

Plants were infested with adult aphids 9 and 26 days after the seed was planted. At the 9-day interval, all concentrations killed 100 per cent of the aphids in 24 hours, and 10 per cent were dead in the checks. At the 26-day interval, the 0.2 and 0.05 ml. concentrations killed all aphids in 48 hours, and 20 per cent were dead in the checks. There were not sufficient aphids to test the 0.1 ml. concentration.

Chemical applied to seed before it was planted.—Pea seed was sprinkled with a solution of octamethyl pyrophosphor-

[1] In cooperation with the Wisconsin Agricultural Experiment Station.

amide diluted with just enough water to wet the seed. The seed was then stirred until the solution was uniformly distributed over it as a thin film. Preliminary tests showed that 350 ml. of solution was required to wet a bushel of seed. The seed absorbed most of the liquid in a short time, swelling slightly in the process but not becoming too soft to plant with a drill. It was planted a few hours after treatment.

In the first test the chemical was used at the rates of 25, 58, 80, and 134 grams per bushel of seed. Plants were infested with adult aphids 13, 25, and 33 days after the seed was planted. The mortality never exceeded 30 per cent in 48 hours after the plants were infested.

In the next test higher concentrations of the chemical were used and gum arabic was added in the hope that it would cause more toxicant to adhere to the seed. The two concentrations were 268 grams of the chemical with 4 grams of gum arabic and 358 grams of the chemical with 8.75 grams of gum arabic, each in 500 ml. of total solution per bushel of seed. Plants were infested with adult aphids at intervals of 13, 18, and 37 days after the seed was planted. Forty-eight hours after the plants were infested, both concentrations gave 100 per cent mortality for the 13-day interval and 98 or 99 per cent for the 18-day interval. For the 37-day interval there was 92 per cent mortality for the lower concentration and 95 per cent for the higher concentration, and no aphids were dead in the check.

These tests, while preliminary, indicated that octamethyl pyrophosphoramide could be expected to be toxic to the pea aphid under field conditions. There was no noticeable foliage injury when the chemical was applied to the seed before it was planted.

FIELD TESTS.—*Mist sprays applied to plants.*—Because so little was known regarding the effect of octamethyl pyrophosphoramide upon the foliage or the canned product, only limited tests were made on small unreplicated field plots of peas. The commercial product used contained 4 pounds of octamethyl pyrophosphoramide per gallon and was applied by a mist blower in 10 gallons of water per acre. Plots in a field of Perfection peas were sprayed with 1 and 0.5 pound of the chemical per acre on June 14, when the plants were 5 to 6 inches high, and with 1 pound on July 8, when the plants were about 20 inches high. Sweep-net counts of the surviving aphids 9 and 12 days after the June application showed 98 to 100 per cent reduction as compared with the untreated check. The reduction 21 days after this application was 100 per cent for the 1-pound dosage and 84 per cent for the 0.5-pound dosage. One day after the July application the reduction was 91 per cent, and it ranged from 96 to 100 per cent 18 days after application. There was no noticeable foliage injury in these tests.

Chemicals applied to seed before it was planted.—Two small-plot tests (Nos. 1 and 2) were conducted to determine under field conditions the effectiveness and lasting qualities of systemic phosphates applied to pea seed in controlling the pea aphid on the developing plants. Each plot consisted of two rows of Perfection peas 6 inches apart. In the first test the plots

Table 1.—Toxicity to the pea aphid of systemic phosphate insecticides applied to pea seed on May 13, 1950. Test No. 1.

Material in Grams of Active Ingredient per Acre	Aphids Surviving per 30 Plants and Reduction in Infestation for Indicated Interval After Treatment					
	47 days		53 days		61 days	
	Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
Octamethyl pyrophosphoramide						
125	170	45	376	19	756	40
250	102	67	236	49	702	45
500	116	62	273	41	595	53
1000	60	80	206	56	437	66
500+gum arabic 8.75	64	79	272	42	562	56
A trialkyl thiophosphate						
500	172	44	383	17	793	37
Significant difference at 5% level	70	—	94	—	242	—
Check, untreated	307	—	465	—	1267	—

were 50 feet long and were planted with a garden seeder on May 13. In the second test the plots were only 20 feet long and were planted by hand on July 5. Each treatment, together with an untreated check, was replicated 6 times in randomized blocks. No nitrogen-fixing bacteria inoculum was applied to the seed, as is usual, nor was any commercial fertilizer used in planting.

The solution of phosphates was poured over the seed in wide-mouth gallon jars. The jars were shaken until all the seeds were coated with a thin film of material. They were then poured out and well distributed on a flat surface to dry before being planted.

In test No. 1 the aphids were counted on 10 plants at each of three random locations in each plot. The aphid infestation, however, developed very slowly and remained so light even on the checks that infestation counts were not warranted until 6 weeks after treatment.

For the first five treatments (Table 1) octamethyl pyrophosphoramide of approximately 90-per cent purity was used. Different quantities were diluted with water to make 350 ml. of total solution per bushel of seed. For the sixth treatment a product containing 32.1 per cent of a trialkyl thiophosphate was used.[2] At this concentration there was sufficient volume to wet the seed without dilution with water. The materials were applied to the seed at different rates in order to give different dosages when the seed was planted at the rate of 4 bushels per acre.

Analysis of the surviving aphids disclosed that octamethyl pyrophosphoramide at the rate of 1000 grams, or a little over 2 pounds, per acre was consistently superior to the first and last treatments. On two occasions 500 grams of this toxicant when combined with gum arabic was superior to the first and last treatments.

It is unfortunate that the aphid infestation was too low for the evaluation of the treatments during the early development of the plants, when the most pronounced toxic effects would be expected. Forty-seven days after treatment, when the plants had been up 38 days, the treatments showed varying degrees of effectiveness (Table 1). Subsequently, the effectiveness of all treatments decreased.

In test No. 2 the aphids were counted on 10 plants at each of two random locations in each plot. An octamethyl pyrophosphoramide of approximately 90-per cent purity was used in the first four treatments (Table 2). This material was from a different source than that used in the first test. The same trialkyl thiophosphate material, containing 32.1 per cent of active ingredient, used in the previous test was used in the fifth treatment.

Again, the infestation increased very slowly so that it was 30 days after planting, or 24 days after the peas were up, before infestation counts were warranted. At this time the second, third, and fourth treatments were giving fairly good control. However, 47 days after planting the control had decreased for all treatments. Analysis of surviving aphids disclosed that the third and fourth treatments were consistently superior to the first, and in two instances to the fifth treatment.

[2] A high concentration of this material was not available at the time this test was made.

Table 2.—Toxicity to the pea aphid of systemic phosphate insecticides applied to pea seed on July 5, 1950. Test No. 2.

Material in Grams of Active Ingredient per Acre	Aphids Surviving per 20 Plants and Reduction in Infestation for Indicated Interval After Treatment					
	30 days		36 days		47 days	
	Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
Octamethyl pyrophosphoramide						
250	10	26	10	72	20	30
500	2	82	4	88	17	40
1000	1	90	4	90	10	65
500+gum arabic 8¾	2	89	4	89	10	64
A trialkyl thiophosphate						
500	4	68	17	52	24	16
Significant difference at 5% level	4.6	—	5	—	9	—
Check, untreated	13	—	36	—	28	—

Results of the field seed-treatment experiment suggest that at least 500 grams of octamethyl pyrophosphoramide, or approximately 1 pound per acre, will be required to provide 80 per cent control of the pea aphid and that the effectiveness of this insecticide is enhanced by the addition of gum arabic. No noticeable foliage injury occurred in this experiment.

CONCLUSIONS.—Greenhouse tests showed that octamethyl pyrophosphoramide was toxic to the pea aphid when solutions were sprayed on pea plants, poured on the soil in which the plants grew, and when pea seed was treated before being planted. In field tests pea plants sprayed with solutions of this material were highly toxic to the aphid. When pea seed was treated before being planted, octamethyl pyrophosphoramide provided significant control of the pea aphid for approximately 6 weeks after treatment in a season when the infestation was very slow in developing.

LITERATURE CITED

David, W. A. L. and B. A. Kilby. 1949. Preparation and insecticidal action of *bis*(*bis*-dimethylamino)-phosphonous anhydride. Nature [London] **164:** 522–3.

David, W. A. L. 1950. Insecticidal action of radioactive *bis*-(*bis*-dimethylamino)-phosphonous anhydride. Nature [London] **166:** 72.

Ivy, E. E., Wm. Iglinsky, Jr., and C. F. Rainwater. 1950. Translocation of octamethyl pyrophosphoramide by the cotton plant and toxicity of treated plants to cotton insects and a spider mite. JOUR. ECON. ENT. **43**(5): 620–6.

Ripper, W. E., R. M. Greenslade, and L. A. Lickerish. 1949. Combined chemical and biological control of insects by means of a systemic insecticide. Nature [London] **163:** 787–9.

Ripper, W. E., R. M. Greenslade, and G. S. Hartley. 1950. A new systemic insecticide bis(bisdimethylamino phosphonous) anhydride. Bul. Ent. Res. **40**(4): 481–501.

Schrader, G. 1946. Kontakinsekticide und Mittel für die Innentherapie von Pflanzen auf Grundläge von Stickstoffhaltigen Phosphorsäurederivaten. Final Report, British Intelligence Objectives Sub-Committee No. 1095, 45–50 (London 1948).

Smith, Floyd F., R. A. Fulton, and S. A. Hall. 1950. Toxicity of organic phosphates to the two-spotted spider mite and the foxglove aphid. JOUR. ECON. ENT. **43**(5): 627–32.

Toxicity of Certain Phosphorus Compounds to Cotton Insects[1]

J. C. GAINES,[2] E. E. IVY[3] and C. E. KING[2]

For the past several years an attempt has been made to evaluate a number of phosphorus compounds relative to their control of injurious cotton insects. Two of the compounds, tetraethyl pyrophosphate and parathion, have been used extensively in the control of aphids and red spider mites. Because of the extreme toxicity of these compounds to higher animals, efforts have been made to develop different phosphorus compounds which might serve to control insects and yet be harmless to warm-blooded animals. Several such compounds were tested by Magee and Gaines (1950). These compounds which were less toxic to higher animals also proved to be less toxic to insects than parathion. Other new phosphorus compounds have been evaluated for control of aphids and spider mites at this Station by Gaines *et al.* (1950) and Ivy *et al.* (1950).

The laboratory and field tests herein reported were conducted at College Station, Texas, during 1950. Three new phosphorus compounds, 4049,[4] 4018[5] and 4124,[6] were compared as sprays and dusts with other materials for the control of several pests of cotton. The spray emulsions were made from miscible oil concentrates and the dusts were made by diluting the concentrated dusts with an inert clay. The procedure used in these tests has been described in the journal articles referred to above.

Spider Mites: The spider mite, *Sep-*

[1] Technical article No. 1426, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture. A. L. Scales and L. J. Gorzycki assisted in making these tests. The compounds were furnished by American Cyanamid Company.

[2] Texas Agricultural Experiment Station.

[3] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.

[4] 4049 = S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate. Later chemical analysis of compound 4049 indicated that the material used in making the emulsion concentrate contained only 65% of technical compound.

[5] 4018 = S-(1,2-dicarbomethoxyethyl) 0,0-diethyl dithiophosphate.

[6] 4124 = 0,0-dimethyl 0-2-chloro-4-nitrophenyl thiophosphate.

Table 1.—Dosage-mortality relationship of the compounds indicated for red spider mite control.

Treatment	Pounds of Active Ingredients per Acre Required to Give— 50 Per Cent Mortality	90 Per Cent Mortality	Slope of Line
TEPP	0.003	0.005	7.9
Parathion	0.008	0.015	4.3
TM-4049	0.296	0.634	3.9
TM-4018	0.257	0.568	3.7
TM-4124	0.135	0.626	1.9

tanychus texazona McG., was cultured in the laboratory for use in these tests. Twenty-four hours after transferring approximately 25 mites per plant to a number of cotton seedlings which were grown in a nutrient solution, the insecticides were applied. Four replicate plants were treated with each dosage of spray emulsion. Ten dosages were required involving 1000 mites to establish each dosage-mortality curve. These curves are shown in figure 1, while the dosages required to kill different percentages of the mite population and also the slope of the lines are compared in table 1. The data regarding tetraethyl pyrophosphate and parathion were reported by Gaines *et al.* (1950) and are included herein for comparison.

Parathion and tetraethyl pyrophosphate proved to be more toxic to spider mites than either of the new phosphorus compounds. At the 50 per cent mortality point, compound 4018 proved slightly more toxic than TM-4049. Both compound 4018 and 4049 were less toxic than TM-4124. The slopes of the dosage-mortality lines for TM-4018 and TM-4049 compared favorably to that of parathion

Table 2.—Dosage-mortality relationship of the compounds indicated for cotton aphid control.

Treatment	Pounds of Active Ingredients per Acre Required to Give— 50 Per Cent Mortality	90 Per Cent Mortality	Slope of Line
Parathion	0.047	0.445	1.3
TM-4049	0.082	0.579	1.5
TM-4018	0.038	0.115	2.7
TM-4124	0.016	0.128	1.4

Table 3.—Results of field tests to determine the effectiveness of the compounds indicated for aphid control.

Treatment	Dosage[1]	Initial Population[2]	Per Cent Reduction After— 1 day	2 days
TM-4049	0.4	2602	96.4	99.2
TM-4124	0.3	2912	98.1	99.8

[1] Pounds of active ingredients per acre.
[2] Number of aphids per 100 square inches.

and were considerably steeper than the line for TM-4124, indicating a greater toxicity at the higher dosages.

Cotton Aphids: Cotton aphids, *Aphis gossypii* Glov., were likewise cultured in the laboratory for their use in these tests. The testing procedure was of the same manner as used for the spider mites. The dosage-mortality curves are shown in figure 2. The dosages required to kill different percentages of the aphid population and also the slope of the lines are compared in table 2.

TM-4124 was more toxic to aphids than either parathion, TM-4018 or TM-4049 at the 50 per cent mortality point. The slope of the dosage-mortality curve for TM-4124 was not as steep as the slope of the curve for 4018, indicating that TM-4018 was more toxic than TM-4124 at the higher dosages. The slope of the mortality curve for TM-4018 was also steeper than the slope for either TM-4049 or parathion. Two of these compounds, TM-4049 and TM-4124 were tested also in the field against aphids.

Table 4.—Results of field cage tests to determine the effectivenss of compounds indicated for boll weevil control.

Treatment[1]	Dosage[2]	Per Cent Mortality
TM-4049	2.00	82
	1.50	30
	1.25	35
	1.00	32
TM-4018	2.00	59
	1.50	39
	1.25	29
	1.00	21
TM-4124	2.00	90
	1.00	57
	0.75	51
Toxaphene	2.00	24
	1.00	19

[1] All materials applied as spray emulsions.
[2] Pounds active ingredients per acre.

Table 5.—Results of field cage tests to determine the effectiveness of compounds indicated for boll weevil and bollworm control.

Treatment[1]	Dosage[2]	Per Cent Mortality	
		Boll Weevils	Boll-worms
	Experiment 1		
TM-4049	2.5	96	45
TM-4049	1.0	87	38
TM-4049	0.5	58	6
TM-4124	2.5	100	0
TM-4124	1.0	99	0
TM-4124	0.5	90	2
Toxaphene	2.0	92	82
	Experiment 2		
TM-4124	1.6	89	24
TM-4124	0.8	69	21
TM-4124	0.4	38	19
TM-4124	0.2	22	20
Toxaphene	4.0	61	100
Toxaphene	2.0	47	95
Toxaphene	1.0	22	67
Toxaphene	0.5	10	39
TM-4124 plus Toxaphene (1-5)	0.6	21	64
"	1.2	46	84
"	1.8	79	96

[1] All dusts applied at the rate of 10 pounds per acre.
[2] Pounds of active ingredients per acre.

A severe infestation of aphids which developed in fields of cotton in this area provided an opportunity to evaluate the phosphorus compounds. In determining the population of aphids, a count was made on one square inch of leaf surface on the fourth leaf from the top of the plant on each of 100 consecutive plants in each plat. The treatments were replicated four times. The emulsion sprays were distributed from a compressed air sprayer mounted on 2 wheels. The sprayer was operated at 60 pounds pressure, the boom supported 3 nozzles to each row and delivered approximately seven gallons of spray per acre. The reductions in the aphid populations are compared in table 3. TM-4049 and TM-4124 applied at rates of 0.4 and 0.3 pounds per acre, respectively, gave excellent aphid control.

Boll Weevil and Bollworm: Tests to evaluate the phosphorus compounds for boll weevil, *Anthonomus grandis* Boh., and bollworm, *Heliothis armigera* (Hbn.), control were made in cages in the field. Individual plants were either sprayed or dusted with a predetermined dosage of insecticide prior to caging and releasing the insects in them. A minimum of three

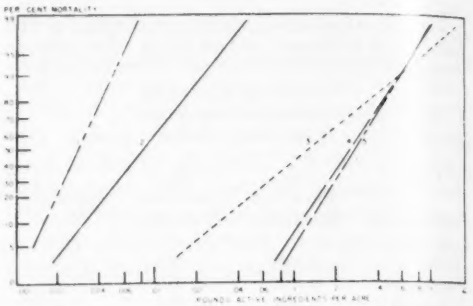

FIG. 1.—Dosage-mortality curves for the toxicity of the following insecticides to spider mites: (1) TEPP, (2) parathion, (3) 4124, 0,0-dimethyl 0-2-chloro-4-nitrophenyl thiophosphate, (4) 4018, S-(1,2-dicarbomethoxyethyl) 0,0-diethyl dithiophosphate and (5) 4049, S-(1,2-dicarbethoxyethyl), 0,0-dimethyl dithiophosphate.

replicates of each dosage and of checks was included in each experiment. Twenty-five weevils and 10 bollworms were placed in each cage or replicate.

The results of tests against boll weevils only are shown in table 4. TM-4124 proved more effective than either TM-4049 or TM-4018 for boll-weevil control. These tests were made late in the season at a time when high dosages of insecticides were required to produce high percentages of mortality.

Comparisons of the efficacy of two of the phosphorus compounds when applied in dust form for boll weevil and bollworm control are shown in table 5. TM-4124 gave better results in the control of boll weevils than TM-4049, while TM-4049 proved more effective against the bollworm than TM-4124. Neither of these phosphorus compounds proved as effec-

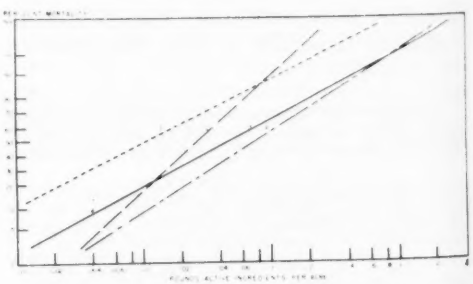

FIG. 2.—Dosage-mortality curves for the toxicity of the following insecticides to cotton aphids: (1) 4124, 0,0-dimethyl 0,2-chloro-4-nitrophenyl thiophosphate, (2) 4018, S-(1,2-dicarbomethoxyethyl) 0,0-diethyl dithiophosphate, (3) parathion, and (4) 4049, S-(1-2, dicarbethoxyethyl) 0,0-dimethyl dithiophosphate.

tive against bollworms as toxaphene.

Since TM-4124 gave poorer control of bollworms than toxaphene and quicker kill of weevils than toxaphene, it was deemed advisable to test several mixtures of the two insecticides for the control of both pests. Results of these tests are shown in table 5. A mixture containing 3 per cent of TM-4124 and 15 per cent of toxaphene proved highly effective against both boll weevils and bollworms. Several dosages of the two compounds were included in the test to determine the compatibility of the materials. The data was analyzed by Wadley's (1945, 1949) short-cut procedures for studying synergism in insecticides. The percentage mortalities obtained from the several mixtures of TM-4124 and toxaphene were no greater than would have been expected from the sum of the independent actions of the two compounds.

Summary: The new phosphorus compounds TM-4049, S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate, TM-4018, S-(1,2-dicarbomethoxyethyl) 0,0-diethyl dithiophosphate, and TM-4124, 0,0-dimethyl 0-2-chlor-4-nitrophenyl thiophosphate proved less toxic than either tetraethyl pyrophosphate or parathion for spider mite control. TM-4124 was more toxic to mites at the 50 per cent mortality level than either TM-4018 or TM-4049 while the compounds had about the same degree of effectiveness at the high levels of mortality.

In laboratory tests TM-4124 proved highly toxic to aphids and in a field test compounds TM-4124 and TM-4049 applied at 0.3 and 0.4 pounds per acre, respectively, gave excellent control.

Neither of the phosphorus compounds tested proved as toxic to the bollworm as toxaphene. TM-4124 proved effective against the boll weevil. A mixture containing 3 per cent of TM-4124 and 15 per cent of toxaphene proved effective for both boll weevils and bollworms.

LITERATURE CITED

Gaines, J. C., E. E. Ivy, H. A. Dean, and A. L. Scales. 1950. Toxicity of various sulphur and phosphorus compounds applied as sprays on spider mites and aphids. JOUR. ECON. ENT. 43(5): 614.

Ivy, E. E., Wm. Iglinsky, Jr., and C. F. Rainwater. 1950. Translocation of octamethyl pyrophosphoramide by the cotton plant and toxicity of treated plants to cotton insects and a spider mite. JOUR. ECON. ENT. 43(5): 620.

Magee, W. J. and J. C. Gaines. 1950. Toxicity of phosphorus compounds to various insects. JOUR. ECON. ENT. 43(3): 281.

Wadley, F. M. 1945. The evidence required to show synergistic action of insecticides and a short-cut in analysis. U. S. Bur. Ent. and Plant Quar. E T 223.

Wadley, F. M. 1949. Short-cut procedure for error estimate in laboratory studies of synergism in insecticides. U. S. Bur. Ent. and Plant Quar. E T 275.

Status of Oriental Fruit Fly Parasites in Hawaii[1]

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Since 1947 one predator and 13 species of parasites of the Oriental fruit fly, *Dacus dorsalis* Hendel, have been released in Hawaii by the Territorial Board of Agriculture and Forestry. The study of establishment, spread, and effectiveness of these introduced beneficial insects was assigned to the University of Hawaii by the fruit fly policy committee representing the various agencies[2] cooperating on the Oriental fruit fly project. Four of the parasites, all species of *Opius* (Hymenoptera-Braconidae), are now known to be established. This paper is concerned with the role that these opiines have played so far in the biological control of *D. dorsalis*.

METHODS.—Studies of the establishment and progress of the parasites have been carried out mainly by means of fruit collections made on the major islands of the Hawaiian group. Monthly collections have been made on Oahu, where our laboratory is located, and less frequent but regular collections made on the other

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[2] Territorial Board of Agriculture and Forestry, U.S.D.A., Oriental Fruit Fly Investigations, Hawaiian Sugar Planters' Association, Pineapple Research Institute, University of California, and University of Hawaii.

islands. These collections have enabled us to follow the spread and increase in numbers of the established parasites, to study their interrelationships, and to maintain a constant lookout for other liberated *D. dorsalis* enemies.

The intensive studies conducted on Oahu have centered around a series of permanent collecting sites distributed over the island in areas of wild guava. Guava (*Psidium guajava* L.) covers large acreages on the various islands in the Territory and is considered the major host of *D. dorsalis*. Its fruits are available in varying quantity throughout the year. Permanent collecting sites were established so that an accurate chronological history of parasitization could be obtained. In addition, it was felt that data from these sites might help us to appraise some of the ecological factors influencing both the fly and parasite populations. The original number of permanent collection sites was 42 but three of these were destroyed by factors beyond our control. Samples of ripe fruits that have fallen to the ground, if available, have been collected monthly from each of the sites. The larvae have been removed from these fruits, transferred to blended papaya-yeast medium and held in special containers in an incubation room (Newell *et al.* 1951). Records of parasitization based on collections handled by the transfer method have been obtained monthly since October, 1949.

Prior to October 1949, collections were taken irregularly from scattered localities and the guavas held in bulk holding boxes as whole fruits. Because of high larval and pupal mortality this procedure was abandoned when the permanent sites were established. However, the data obtained from these earlier collections show the trends in parasitization from December, 1948 to October, 1949, and therefore are used in this discussion. The early collections were made principally by Gordon Mainland and Satoru Shimono former members of the Hawaii Agricultural Experiment Station staff.

During the period October, 1949 to December, 1950, 56,078 flies and parasites were recovered from approximately 13,000 guava fruits in 391 collections made at the permanent sites on Oahu. Monthly percentages of parasitization have been calculated from the numbers of recovered parasites and flies. Thousands of additional flies and parasites were recovered from the periodic guava collections made on the other islands. These collections were handled in the same manner as those made on Oahu.

In addition to guavas, a variety of fruits including mango (*Mangifera indica* L.), surinam cherry (*Eugenia uniflora* L.), false kamani (*Terminalia catappa* L.), papaya (*Carica papaya* L.), loquat (*Eriobotrya japonica* Lindl.), and rose apple (*Eugenia jambos* L.) have been held by the U.S.D.A. funnel method. In this method whole fruits are placed in a funnel fitted over a battery jar provided with a juice trap. About an inch of clean sand is put in the jar for the larvae to drop onto to pupate.

PARASITES AND THEIR CHARACTERISTICS.—The four parasites of *D. dorsalis* known to be established in Hawaii are: *Opius longicaudatus* (Ashm.), *Opius* sp.,[3] *O. incisi* Silv., and *O. oophilus* Full. All four species are solitary internal parasites, the adults of which emerge from the host puparia. Some of the characteristic habits of these species are discussed below.

Opius longicaudatus: This parasite usually lays its eggs in late second and third instar fruit fly larvae. Females are commonly seen on over-ripe fruits that have fallen to the ground as well as on ripe fruits on the trees. Such fruits usually harbor larger host larvae. The female parasite punctures the skin of the fruit with its ovipositor in order to deposit its eggs in the *D. dorsalis* larvae beneath. The sex ratio of specimens reared from field collected fruits has been about 1:1.

Opius sp.: This species attacks first instar host larvae. The female normally inserts its ovipositor through the fruit fly egg puncture and deposits its eggs in the first instar larvae concentrated in or near the oviposition cavity. The ovipositor is sometimes inserted directly through the skin of soft ripe fruits. Adults are rarely seen on fruits on the ground and appear to restrict their activity to mature green and ripe fruits on the trees. The sex ratio has been about 1.8:1 in favor of females.

Opius incisi: Little is known of the

[3] This parasite has been called *Opius persulcatus* (Silv.) by workers in Hawaii. However, its taxonomic status is doubtful and therefore it is referred to as *Opius* sp. in this paper.

biology of *O. incisi;* however, scanty records indicate that it attacks the larger host larvae. It probably has oviposition habits similar to those of *O. longicaudatus.* The sex ratio of the small number of adults so far recovered has been about 1:1.

Opius oophilus: O. oophilus is an egg-larval parasite. The female inserts its ovipositor through the fruit fly oviposition puncture and deposits its eggs in the host eggs. Adults are rarely seen on fallen fruits. The ratio of females to males has been about 1.5:1.

In addition to the parasites mentioned above, the following species of entomophagous insects have been liberated in Hawaii during the biological control campaign against the oriental fruit fly but apparently have not become established on *D. dorsalis: Thyreocephalus albertisi* Fauvel (predatory staphylinid), *Trybliographa daci* Weld, *Bracon fletcheri* Silv., *Syntomosphyrum indicum* Silv., *Opius formosanus* Full., *O. deeralensis* Full., *O. fijiensis* Full., *O. skinneri* Full., and two unidentified opiines (Weber, 1951).

HISTORY OF PARASITIZATION.—The parasites of *Dacus dorsalis* have apread very rapidly over the Territory and are now abundant on all of the major islands. Trends of parasitization on Oahu are shown in figures 1 and 2 and those for Hawaii and Maui in figures 3 to 5. The following discussion is an elaboration of the developments shown in these graphs.

Developments during 1948 and 1949. Following the initial liberations in 1948, the parasites quickly made substantial progress. By the end of 1949, excepting for *Opius oophilus,* they were widely distributed on Oahu and well established on Hawaii, Maui, and Kauai (Bess *et al.* 1950). *O. longicaudatus* and *Opius* sp. were responsible for almost all the parasitization during this period.

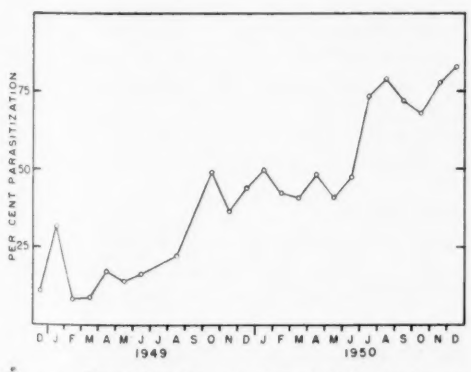

FIG. 1.—Parasitization of oriental fruit fly larvae in guava fruits collected on Oahu during the period, December, 1948 to December, 1950.

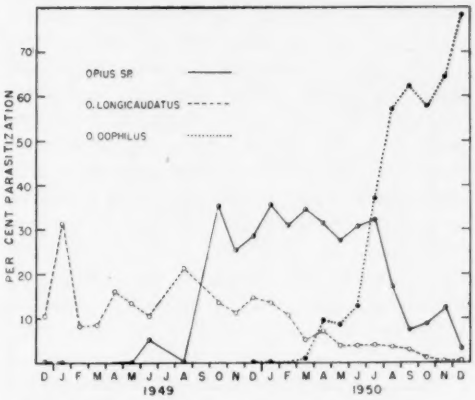

FIG. 2.—Breakdown of the parasitization shown in figure 1 by species.

Opius longicaudatus, the first parasite to become established, was recovered on Oahu soon after release in the fall of 1948, and spread rapidly during the next twelve months. By the fall of 1949 it had become very abundant on Oahu and at a number of localities on the other islands.

Opius sp., also became established in the fall of 1948 but did not become very abundant until a year later when it suddenly replaced *O. longicaudatus* as the predominant parasite on Oahu (Fig. 2) Prior to 1950, however, it was not of much importance on the other islands.

Although *O. incisi* was recovered as early as the spring of 1949 and became well distributed over the Territory, it did not occur in large numbers.

O. oophilus was encountered in only one collection in 1949. It was recovered in December from guavas taken at Waikane, Oahu, and was thought to be a melanistic form of *Opius* sp. However, it was later found to be a distinct species (van den Bosch and Haramoto 1951), and has been described as new by Fullaway (1951). *O. oophilus* is similar to *Opius* sp. and was probably released as the latter species in Hawaii.

Developments during 1950. During 1950 parasitization of oriental fruit fly larvae increased tremendously throughout the

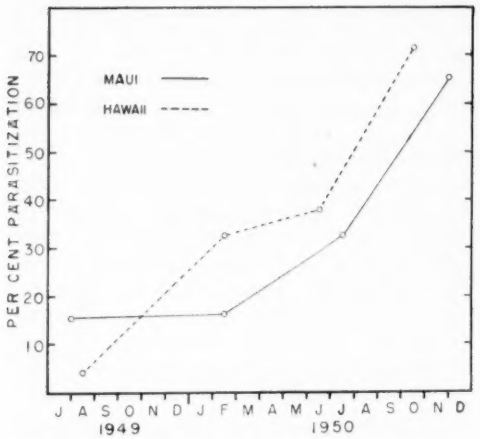

FIG. 3.—Parasitization of Oriental fruit fly larvae in guava fruits collected on Maui and Hawaii during 1949 and 1950.

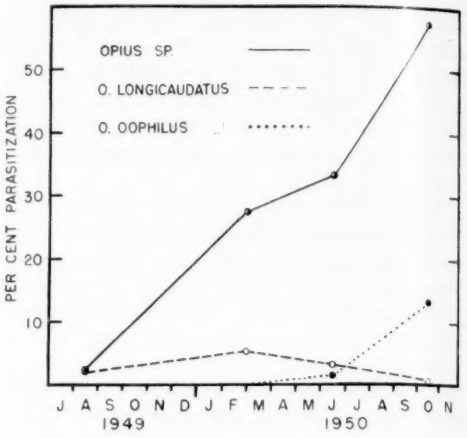

FIG. 5.—Breakdown of the parasitization on Hawaii shown in figure 3 by species.

Territory. It was especially high on Oahu where a peak average of 82.9 per cent parasitization in larvae reared from guava was reached in December (Fig. 1). By the late fall parasitization on Hawaii and Maui approached that of Oahu. At this time the averages for the Hawaii and Maui guava collections were 71.4 and 65.4 per cent, respectively (Fig. 3). Limited collections taken on Moloaki and Lanai indicated that sharp increases in parasitization also occurred on these islands during the year.

Opius oophilus was largely responsible for the marked increase in parasitization which occurred on Oahu. This egg-larval parasite became abundant in the late spring and early summer when large numbers were produced from the heavily infested spring-summer guava crop (van den Bosch 1951a). By July it greatly outnumbered the other species and during the last five months of the year was overwhelmingly predominant (Fig. 2), constituting 94.4 per cent of the parasites recovered in December. *Opius* sp. produced most of the remaining parasitization, while *O. longicaudatus* contributed only a negligible amount. Substantial numbers of the latter species were still being produced from certain infested fruits other than guava at this time, however.

On Hawaii and Maui the high parasitization was primarily produced by *Opius* sp. which increased sharply in abundance during the spring and summer, and replaced *O. longicaudatus* as the most

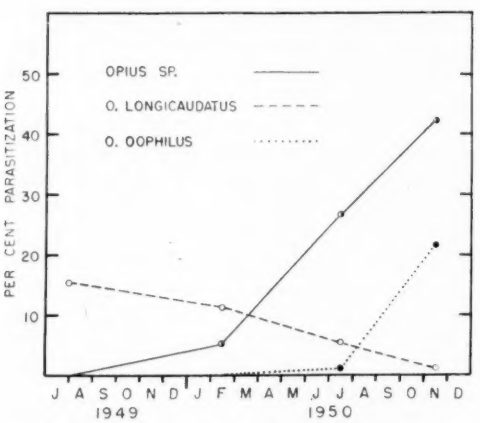

FIG. 4.—Breakdown of the parasitization on Maui shown in figure 3 by species.

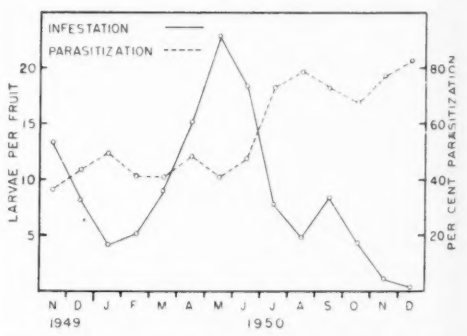

FIG. 6.—Guava infestation and larval parasitization in fruits collected at the permanent Oahu collecting sites during the period November, 1949 to December, 1950.

important parasite (Figs. 4 and 5). Recent collections show that *O. oophilus* has also increased in abundance on these islands (Figs. 4 and 5) and it probably will replace *Opius* sp. as the predominant parasite there in the near future.

As was the case in 1949, only small numbers of *Opius incisi* were recovered in 1950 and this parasite was of little importance during the year.

INFESTATION TRENDS IN GUAVA FRUITS.—Unfortunately continuous quantitative records of guava infestation dating from the time that *Dacus dorsalis* was discovered in Hawaii are not available. However, the infestation was known to be severe in 1947 and 1948 and scattered records show that it was heavy during the first ten months of 1949. Since November, 1949, infestation records based on the number of larvae per guava fruit have been obtained from the collections made at the permanent sampling sites on Oahu (Fig. 6). These records show that the infestation during the winter of 1949–50 reached a low point of about 4.2 larvae per fruit in January. In the spring it increased in severity and the guavas collected from the spring-summer crop were quite heavily infested, averaging 23.9 larvae per fruit in May, and 81.9 per fruit in June. However, as the season advanced, infestation declined more or less steadily, and in December the average was only 0.44 larva per fruit. During November and December a high percentage of the fruits was clean and infestation was clearly less severe than in the corresponding months of 1949. In addition to the guava infestation records, fly trapping records taken by several workers in the Territory show that there has been a great reduction in the abundance of flies during recent months. Furthermore, numerous reports by individuals in the Honolulu area indicate that the infestation of backyard fruits was much less severe in 1950 than during the two previous years.

DISCUSSION.—There is little doubt that the parasites of *Dacus dorsalis* have appreciably reduced the abundance of this pest in Hawaii and continued rates of parasitization cause speculation that further reduction can be anticipated. Some of the factors that have been of importance in this biological control campaign are discussed below.

One of the most impressive developments that has occurred so far has been the rapid rise in abundance and swift spread of the four opiine parasites. This supports the hypothesis[4] that potentially successful parasites, when released in a new area, demonstrate their effectiveness within a relatively short time. Failure to recover any of the other liberated species after months of effort is an indication that they will probably not become important. Prolonged intensive efforts to rear, liberate, and recover such parasites in this and other biological control programs are likely to prove futile.

The key to the success already attained in the biological control of *Dacus dorsalis* probably lies in the oviposition habits of *Opius oophilus* and *Opius* sp. The ability of these species to parasitize the host in the highly vulnerable egg and first larval stages (when it is located at or near the fruit surface) has enabled them to produce very high rates of parasitization. Both are capable of parasitizing most or all larvae in individual fruits, and parasitization ranging from 99 to 100 per cent has been common in such fruits. Although *O. oophilus* and *Opius* sp. were the first fruit fly parasites known to attack their host in the early developmental stages, two new egg-larval parasites are now being propagated in Hawaii and there is some evidence that similar parasites of other tephritids may be found. The utilization of such parasites, if they could be found, might be of considerable aid in biological control programs directed against these flies.

Another conspicuous development that has taken place during the past two years has been the successive rise to predominance on Oahu of each of the three parasites which has so far played an important role in the parasitization of *Dacus dorsalis* (Fig. 2). All the factors which have contributed to this succession are not known but it is felt that the basic causes are fairly well understood. The early rise to predominance of *Opius longicaudatus* was apparently enhanced by the liberation of large numbers of insectary reared specimens. This parasite was more easily handled under insectary conditions than *Opius* sp. and as a result much larger

[4] Clausen, C. P. 1950. The time factor in biological control. Presidential address, sixty-second annual meeting, American Association of Economic Entomologists.

numbers were produced and released in the early stages of the program (Bess, *et al.* 1950). Although *O. longicaudatus* became very abundant during 1949, and parasitized a substantial percentage of the fruit fly larvae on Oahu, fruit infestation remained high and the majority of host larvae were escaping parasitization at the time *Opius* sp. first became prominent. Because of its habit of attacking the vulnerable young host larvae *Opius* sp. was able to produce a relatively high degree of parasitization and soon surpassed *O. longicaudatus* in abundance. This probably was especially true in guavas where the majority of flies are produced. The subsequent replacement of *Opius* sp. by *O. oophilus* seems to have resulted from competitive superiority of the latter. Studies of multiple parasitism involving the two species indicate that eggs of *Opius* sp. do not develop when they are deposited in hosts containing *O. oophilus* larvae (van den Bosch 1951b). This factor appears to have made it possible for *O. oophilus* to replace *Opius* sp. rapidly in the early summer of 1950 when multiple parasitism was very high. Further study is now in progress which should give a fuller understanding of the interactions of the parasite larvae in cases of multiple parasitism.

The adult parasites of *Dacus dorsalis* apparently move very rapidly and in large numbers over considerable distances. This was demonstrated in the early spring of 1950 following a period of complete absence of fruits at many of the collection sites. During the period of fruit scarcity no parasites were observed at these places for as long as 3 months, even though special efforts were made to find them. Nevertheless, in many cases parasitization of larvae taken from the first ripe fruits of the season was 80 per cent or higher. It appears that as fruits ripened and became infested in these areas, large numbers of parasites immigrated from the surrounding countryside. The swift spread of *Opius oophilus* on Oahu during 1950 further illustrates this speedy parasite movement. This phenomenon has been of great importance in the biological control of *D. dorsalis* since it has resulted in high parasitization of larvae in fruits which have short fruiting seasons and are scattered in distribution.

The existence of wild guava which has fruiting characteristics that result in the production of ripe fruits in varying quantity throughout the year has probably contributed greatly to the success of the parasites in Hawaii. It has been estimated that guava lands cover nearly one-third of the area of Oahu alone. Consequently, guava has served as an important wild host reservoir for both flies and parasites. During 1950, parasites were able to build up to, and maintain a high rate of parasitization over a period of several months in infested guavas (Fig. 1). As pointed out above, parasites migrate in large numbers from the wild guava reservoir into such seasonal crops as mango and avocado when they come into bearing. Without guava to maintain the favorable host fruit sequence the parasites might have more difficulty than the long lived flies in surviving during the periods between fruiting of the short seasoned crops. Under this condition the balance between the parasites and their host could be upset, resulting in lower parasitization.

The high degree of parasitization which prevailed at the relatively low host density in the last few months of 1950 (Fig. 1) may be of significance. Although there has not been sufficient time for the parasites to prove themselves under conditions of sustained host scarcity, it is encouraging that they were able to parasitize such a high percentage of the larvae in guavas during November and December of 1950 when the host density was very low. Probably changes will take place in the parasite complex and degree of parasitization as time goes by. Nevertheless, it is felt that the parasites will continue to have a strong influence on the Oriental fruit fly in Hawaii.

SUMMARY.—Liberations of insect enemies of the Oriental fruit fly, *Dacus dorsalis* Hendel, were initiated in Hawaii in 1947. By the end of 1950, 13 parasites and a predator had been released and four parasites, *Opius longicaudatus* (Ashm.), *Opius* sp., *O. incisi* Silv., and *O. oophilus* Full., were known to be established. These parasites made remarkable progress throughout the Territory and by late 1950 host larvae on the islands of Oahu, Hawaii, and Maui were heavily parasitized. Parasitization was especially high on Oahu where a peak average of 82.9 per cent was reached in

infested guava fruits during December of 1950. Most of this parasitization was produced by the egg-larval parasite *O. oophilus*, which became very abundant during the summer of 1950. Infestation trends in guava fruits indicate that the parasites have markedly reduced the abundance of *D. dorsalis*. Continued heavy parasitization is cause for speculation that even further reduction will take place. Certain factors have contributed to the success already attained in the program and some of these are discussed.

LITERATURE CITED

Bess, H. A., Robert van den Bosch, and Frank Haramoto. 1950. Progress and status of two recently introduced parasites of the oriental fruit fly, *Dacus dorsalis* Hendel, in Hawaii. Proc. Haw. Ent. Soc. **14**(1): 29–33.

Clausen, C. P. 1951. The time factor in biological control. JOUR. ECON. ENT. **44**(1): 1–8.

Fullaway, D. T. 1951. Review of the Indo-Australasian parasites of the fruit flies (Tephritidae). Proc. Haw. Ent. Soc. **14**(2): 243–50.

Newell, I. M., Robert van den Bosch, and F. H. Haramoto. 1951. An improved method of rearing field-collected fruit fly larvae. Proc. Haw. Ent. Soc. **14**(2): 297–99.

van den Bosch, Robert. 1951a. Notes on natural enemies of tephritid fruit flies. Proc. Haw. Ent. Soc. **14**(2): 230–31.

van den Bosch, Robert. 1951b. Notes on natural enemies of tephritid fruit flies. Proc. Haw. Ent. Soc. **14**(2): 232–33.

van den Bosch, Robert, and F. H. Haramoto. 1951. *Opius oophilus* Fullaway an egg larval parasite of the oriental fruit fly discovered in Hawaii. Proc. Haw. Ent. Soc. **14**(2): 251–55.

Weber, P. W. 1951. Recent liberations of beneficial insects in Hawaii. Proc. Haw. Ent. Soc. **14**(2): 327–30.

Parasitization of Dipterous Leaf Miners in Cantaloups and Lettuce in the Salt River Valley, Arizona

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Leaf miners, *Liriomyza* spp., have long been recognized as pests of vegetables in the Salt River Valley of Arizona, although observations during the period 1938–1947 indicated that these insects were of minor importance. During the fall of 1947, however, a severe leaf miner infestation was observed in lettuce, and in June and July 1948 leaf miners occurred in outbreak numbers in cantaloups. This infestation was so severe that some fields were abandoned and disked, since at that time no insecticides that would control these pests were known.

After the 1948 leaf miner outbreak in cantaloups, studies were begun to determine the status of parasites affecting these insects. Samples of infested leaves were gathered from the field and placed in ice cream cartons fitted with test-tube windows. They were held in the laboratory at temperatures ranging from 72° to 82° F., constant illumination being provided to insure the attraction of the emerging insects into the tubes. Each sample was held for 4 weeks, which allowed sufficient time for the leaf miners and leaf miner parasites to complete their life cycles and emerge as adults into the test tubes, from which they could be removed and identified. This work is being continued, but the results of 3 years' work (1948–50) are now available. During that period the insects from 347 samples of lettuce or cantaloup leaves have been reared. Most samples consisted of either 25 leaves, or 25 entire plants in the cotyledon or early two-leaf stage. A total of 44,384 leaf miner flies and 18,180 hymenopterous parasites have been reared by this method and identified. A list of the species of parasites reared from leaf miners in cantaloups and lettuce is given in table 1. The relative importance of each of the various parasite species is indicated by the numbers reared from these two crops in 1950. The data in this table, for cantaloups, were obtained from 88 samples taken at approximately weekly intervals from one field. Eight samples, each consisting of either 10 leaves or 10 small

[1] The assistance of the Division of Insect Identification in identifying the hymenopterous parasites of the leaf miners is gratefully acknowledged.

Table 1.—Hymenopterous parasites of leaf miners reared from infested leaves of cantaloup and lettuce. Salt River Valley, Ariz., 1950.

Species	Numbers of parasites from—	
	Cantaloup	Lettuce
Halticoptera aenea (Walk.)	103	1,501
Derostenus arizonensis Cwfd.	93	294
Solenotus begini (Ashm.)	68	244
Closterocerus utahensis Cwfd.	12	16
Solenotus websteri Cwfd.	11	2
Diaulinopsis callichroma Cwfd.	4	58
Derostenus variipes Cwfd.	2	4
Chrysocharis parksi Cwfd.	3	41
Anagrus giraulti Cwfd.[1]	—	—
Trichogramma minutum (Riley)	10	8
Opius dimidiatus Ashm. *Opius aridis* Gahan *Opius sututalis* Gahan *Opius* sp. *A* *Opius* sp. *B*	29	48
Total	335	2,216

[1] Not obtained in 1950.

plants, were taken from different places in the field on each sampling date. Sampling was begun on March 29, when the plants were in the cotyledon stage, and was continued until cantaloup harvest on June 12. Data for lettuce were obtained from 53 samples taken at weekly intervals from four different fields. One sample, consisting of either 25 leaves or 25 small plants, was taken from each field on a given sampling date. Sampling was begun on September 15, when the plants were in the cotyledon stage and was continued until January 25, when populations of leaf miners and parasites became extremely low.

It will be noted that the distribution of the various species of parasites listed in table 1, is different for the two crops. The differences may be attributable to the effect of weather conditions on the leaf miners and parasites at the time of year when the crops were grown. *Halticoptera aenea* (Walk.) was the most important parasite of the leaf miners infesting both lettuce and cantaloups, and from 78 to 92 per cent of the parasitization in both crops was attributable to the first three species of chalcids listed in table 1.

The method of oviposition and the larval development of the various species of parasites are not completely understood, but some information of their life history was obtained. Rearing studies in 1949 on 2,256 leaf miner pupae obtained from leaves of cantaloups, lettuce, and watermelons indicated that *Halticoptera aenea* and *Opius* spp. were internal parasites, the adults emerging from the pupae of the host. Further studies were made by rearing insects from 115 sections of leaves containing only dead leaf miner larvae and from 110 sections containing only live larvae. Emergence from leaf sections containing dead larvae consisted of 22 per cent of *H. aenea*, 61 per cent of other chalcids, and 17 per cent of *Opius* spp. Emergence from the sections containing live larvae consisted of 24 per cent of *Liriomyza* spp., 71 per cent of *H. aenea*, and 5 per cent of other chalcids. These data indicate that the larvae of *H. aenea* ot *Opius* spp. may sometimes kill the leaf miner larvae before pupation, the parasite pupating within the body of the host or nearby in the leaf miner tunnel. However, in *H. aenea* the host insect is usually allowed to complete its larval development, the adult parasite emerging from the pupa of the host. Other chalcids noted to emerge only from leaf sections containing dead leaf miner larvae included *Derostenus arizonensis*, *Closterocerus utahensis*, *Diaulinopsis callichroma*, *Derostenus variipes*, *Solenotus begini*, and *S. websteri*. *Trichogramma minutum* presumably emerged from leaf miner eggs within the leaf tissue, but there was indication that some of these parasites emerged from leaf miner pupae. Only a few individuals of *Anagrus giraulti* have been obtained, and nothing is known regarding the life cycle of this insect. Webster & Parks (1913) state that *Chrysocharis parksi* is an internal parasite and that the adults emerge from the pupa of the host. They also state that *Solenotus begini* and *S. websteri* (both reported as *Diaulinus*) are external parasites of the serpentine leaf miner larvae. They pierce the plant tissue over the body of the leaf miner and deposit their eggs directly on the body of the larva. The young parasite larva feeds externally upon the body of the host, which dies while the parasite larva is very young.

Except in August and early in September, lettuce and cantaloups serve as host plants of leaf miners the year round in the Salt River Valley. Two crops of lettuce are grown in this area—fall lettuce planted about September 1 for harvest late in November, December; and Janu-

Table 2.—Per cent parasitization of leaf miners in lettuce and cantaloups. Phoenix, Ariz., 1948–50.

	SEPTEMBER		OCTOBER			NOVEMBER			DECEMBER			JANUARY			FEBRUARY			MARCH
	1–10	21–30	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–28	1–10
Fall lettuce:																		
1948		7	10	10	60	65	63	36	25	33	41	64	59	91	89			
1949		1	12	6	59	54	79	90	60									
1950	0	5	5	12	61	40	56	55	62	57								
Spring lettuce:																		
1948							3	6	1	3	9	12	3	0	50	8		
1949									8	13	5	10	27	80	33	42	78	50
1950							0	5	5	5	2	2	13	44				

	APRIL			MAY			JUNE			JULY		
	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31
Cantaloups:												
1948:												
Field 1											28	46
Field 2								9	45	52	71	
Field 3										0	2	67
Field 4										32		100
1949		46	41	57	65	39	49	—	54	70		
1950		27	56	39	13	20	32	52	41			

ary, and spring lettuce planted in November for harvest in March and April. Leaf miners are active in both these crops, but are much more numerous in the fall lettuce, largely because of more favorable weather conditions. Cantaloups are planted in March and April, but very little leaf miner activity occurs before April 1, when the plants are still in the cotyledon, or two-leaf, stage. Leaf miner larvae are active all winter, and adults can be found all winter, but numbers are reduced and the life cycle greatly lengthened during that period. During July and August no vegetable crops are grown in this area and the leaf miner populations in other crops are greatly reduced. Webster & Parks (1913) state that Wildermuth, who was studying serpentine leaf miner activity in alfalfa at Tempe, Ariz., in 1912, remarked on the almost total disappearance of all stages of this insect during July and August, followed by its reappearance in September.

The per cent of parasitization of leaf miners throughout the year in lettuce and cantaloups is given in table 2. These data show that parasitization in September, in fall lettuce, starts at a very low level and builds up until the end of October, when over half of the leaf miners are parasitized. In the spring lettuce crop, parasitization again starts at a very low level in November and December and the build-up of parasistes is much slower than in fall lettuce. This is undoubtedly due to comparatively cold weather during the winter months. Total emergence of leaf miners and parasites is also low during the winter. Leaf miners appear in cantaloups soon after the plants are up in April, and parasitization in 1949 and 1950 started at a comparatively high level, which held the leaf miners in check throughout the season. Studies on leaf miner parastization were not begun until after severe damage had occurred to the cantaloup crop in June 1948, and therefore no data on cantaloups are available for that year for the early spring months. However, data from four fields for June and July 1948 are presented in table 2. Leaf miners were numerous at that time and damage was excessive. In Field 1 parasite populations built up in time to save the crop, and this field was harvested. Field 2 was a very early field and, although parasite populations eventually built up sufficiently to control the leaf miners, the leaves were so damaged that the sugar content of the melons was unsatisfactory and the field was abandoned. Field 3 was also abandoned before harvest was complete because of excessive damage by leaf miners, although the parasite population eventually caught up and reduced the leaf miner population practically to zero. Field 4 was a field of late honeydew melons and, although leaf miners had a good start, the population was greatly reduced by parasites and little damage was done to the crop.

Leaf miner damage to lettuce in the Salt River Valley is of little economic concern. Populations sometimes become high on the fall crop, but the increase of

parasites as the season advances, together with the slowing down of leaf miner activity with the approach of winter, confines the damage to the outer leaves, which are ordinarily trimmed off in preparing the crop for market. Leaf miner populations in spring lettuce are considerably lower than in fall lettuce, and the shift of populations from fall to spring lettuce is accompanied by a great reduction in parasite populations. By February the ratio of parasites to leaf miners is again high. Cantaloup plants emerge late in March or early in April and leaf miner flies and chalcid parasites enter the fields in about equal numbers. Therefore leaf miner parasitization on this crop ordinarily starts at a comparatively high level, as shown in table 2. Thus, while leaf miners occur throughout the fall and winter in lettuce, this crop suffers little damage, and by serving as a host of the leaf miners it carries large numbers of parasites through the winter in readiness for attack on leaf miners affecting cantaloups. Anything that interferes with the successful overwintering of these parasites may result in a severe leaf miner outbreak in cantaloups. Just what happened to cause the outbreak of 1948 is not known but available data indicate that parasitization of the leaf miner was low that spring. Insecticide tests on cantaloups in experimental plots in 1950 showed that repeated applications of DDT were ineffective against the leaf miners but reduced the parasite population, resulting in increased leaf miner populations.

SUMMARY.—Studies to determine the species of parasites and the effect of their parasitization on leaf miners attacking lettuce and cantaloups were conducted in the Salt River Valley of Arizona. From 1948 through 1950 the studies consisted of rearing the leaf miners and their parasites from infested leaves, samples of which were obtained at weekly intervals throughout the year. Ten species of chalcids and 5 species of braconids of the genus *Opius* were reared from leaf miner-infested leaves, of which from 78 to 92 per cent of the parasitization was attributed to 3 species of chalcids. Of these parasites *Halticoptera aenea* was the most numerous. This species was found to emerge largely from the pupa of the host and to some extent from dead leaf miner larvae. Most of the other chalcids emerged from the dead leaf miner larvae.

Lettuce and cantaloups furnish almost a year-round environment for leaf miners in the Salt River Valley. Damage to lettuce by this pest was observed to be of little concern. Since leaf miner parasitization reaches a high level on lettuce late in the winter and early in the spring, this crop is considered responsible for the overwintering of large numbers of parasites ordinarily present on young cantaloups in April. Conditions that interfere with the successful overwintering of parasites may result in damage to the cantaloup crop. Results of small-plot experiments in 1950 indicated that repeated applications of DDT to cantaloups were ineffective against infesting leaf miners, but killed the parasites, resulting in an increase in the leaf miner populations.

LITERATURE CITED

Webster, F. M., and T. H. Parks, 1913. The Serpentine Leaf Miner. Jour. Agr. Res. 1(1): 59–87.

LARVAE OF INSECTS, Part II by Alvah Peterson, Ohio State University, Columbus, Ohio. 104 plates of drawings, 416 pages, 8×11. Lithoprinted. Edwards Bros., Ann Arbor, Michigan. Sale price $7.00, distribution by author.

Part II of "Larvae of Insects" is a companion volume of Part I published in 1948. Part II includes larvae of Coleoptera, Diptera, Neuroptera, Siphonaptera, Mecoptera, and Trichoptera. It treats these orders, especially the Coleoptera and Diptera in a manner very similar to the way the Lepedoptera and plant infesting Hymenoptera are handled in Part I. It includes general discussions of characters associated with larvae of each order, keys to families, family names used by various authors, descriptions of larvae of the more common families and lists of common and scientific names of important species.

The most useful portions of the book are the many figures of larvae for each order which show diagnostic characters accompanied with descriptions of species. The volume also contains selected bibliographies, host and habitat indices (for Coleoptera and Diptera), a comprehensive glossary, and a general index.

For students and entomologists, especially workers in extension, quarantine and experiment stations, for biologists interested in wildlife or ecology, for veterinarians, physicians, and workers in public health, especially about army and navy posts, interested in the determination of larvae, this volume plus the information contained in Part I, should prove to be of distinct value.

A Biological Check Method for Evaluating the Effectiveness of Entomophagous Insects[1]

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Evaluation of the effectiveness of entomophagous species in the control of their hosts represents one of the most necessary and desirable phases of biological control. It is highly desirable from the standpoint of proving what effect introduced natural enemies have on their hosts, and it is virtually indispensable in the study of the ecology of already established predators and parasites.

Smith & DeBach (1942) have discussed the need for such evaluation, but state that in biological control the use of test plots and check plots, as ordinarily used in economic entomology, seems not to be feasible for measuring the effect of parasite introduction on population density of the host insect, for the reason that the check plots are almost immediately invaded by the introduced natural enemies.

PREVIOUS METHODS.—Smith & DeBach (1942) suggested the possibility of using sleeves to exclude parasites from hosts on certain branches but permit them to have access to hosts on other branches in the immediate vicinity. In this way the survival of host populations in the presence and absence of parasites might be compared. (A modification of this method is described by DeBach *et al.*, 1949.) The principal drawbacks to the use of the sleeve-check method are the possible modification of the microclimate, interference with parasite dispersion, and protection from wind, which normally might remove some individuals of the pest species.

A simple experimental method for measuring the efficacy of natural enemies, termed the "insecticidal check method," has been described by DeBach (1946). This method utilizes a selective insecticide which is nontoxic to the pest but toxic to the natural enemies involved. A comparison of pest population changes may then be made between trees having natural enemies present or absent. This method has none of the disadvantages of the sleeve-check method but it does have other possible disadvantages, namely, the presence of an insecticidal residue which may make the leaf substratum more suitable to the pest species, and a possible physiological effect on the tree and pest species which may favor increased reproduction of the pest.

NEW METHOD.—The biological check method discussed in the present paper apparently has none of the disadvantages of the other techniques. The biological check employs ants to inhibit or eliminate natural enemies. Any honeydew-feeding ant probably may be utilized. The microclimate is not affected, insecticidal residues are not involved, dispersion is not interfered with, and there is no wind protection. The use of this method appears to be most suitable on tree crops, although it should be applicable to most perennial crops and to many annual crops. Successful utilization of this method will be restricted to pest species not easily disturbed or not attacked by the ant species being used.

The basis of this method lies in the well-known fact that ants disturb or kill the natural enemies of pest species, thereby reducing the effectiveness of these natural enemies. This reduction is more or less in direct proportion to the abundance of the ants. A comparison between a plot heavily infested with ants and an ant-free plot therefore affords an approximate though not complete measure of the effectiveness of the natural enemies as reflected by the differential increase of the pest population in the ant-infested plot. Although experimental comparisons of this type have been employed by a few workers (Horton 1918, Woglum & Borden 1921, and Flanders 1945) to demonstrate the effect of the Argentine ant in causing population increases of certain citrus pests, the deliberature use of ants as a method of measuring the effectiveness of

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natural enemies apparently has never before been suggested. Only two reports (Newell & Barber 1913, Flanders 1945) have claimed that ants may favor population increase of insects other than honeydew producers; and only one report (Flanders 1945) has demonstrated experimentally that ants, through their depression of parasite populations, may cause increases in diaspine scale populations—in that case the yellow scale, *Aonidiella citrina* (Coq.)

Recent studies on citrus have shown that the Argentine ant, *Iridomyrmex humilis* Mayr., may be utilized to measure the effectiveness of natural enemies of the California red scale, *Aonidiella aurantii* (Mask.), as well as of the yellow scale, and of the citrus red mite, *Paratetranychus citri* (McG.). There seems to be no reason why this method should not apply to other diaspine scale insects and mites, as well as to virtually all homopterous honeydew-producing insects.

Field observations on citrus trees have not indicated that the ants favor increase of any of the pests involved, other than by their adverse effect on natural enemies.[5] Horton (1918), after 3 years of study of the Argentine ant in Louisiana and California citrus groves, concluded that "Direct dissemination of orange scales and aphids by the ant is only incidental and is negligible. Indirectly the ants aid in the dissemination of some of these insects by greatly increasing them on particular trees, and from these points of heavy infestation they spread by the usual means." Occasionally, there is a tendency for the ant species observed to prey on individuals of the pest species, but never to the extent of affording control.

On citrus in California, the Argentine ant is the species that is most abundant and most widely distributed. It seems to be the most satisfactory species for use in the biological check method, although the gray field ant, *Formica cinerea neocinerea* Wheeler, would serve as an excellent indicator in certain areas. Local species of honeydew-feeding ants probably can be adapted for use in this method nearly everywhere.

It is essential to this method that an adequate food supply be available to the ants on the ant-infested trees. This frequently occurs naturally in the field through the medium of honeydew-producing insects. Such insects can be artificially colonized if not present naturally. It it is desirable to minimize honeydew-producing or other insects as one of the factors in the complex that is being tested, trees can be chosen which are infested principlally with the pest it is desired to check, ants introduced if necessary, and honey applied artificially to the trees. This has been done experimentally in the laboratory with an Argentine ant colony. The ants had access to one small orange tree and were caused to run over this tree in abundance by streaking honey on the leaves. Grapefruits infested with California red scale were placed in each tree, and the parasite *Aphytis* "A" was colonized in equal numbers on each tree. On the ant-infested tree only 6.8 per cent as many scales were parasitized as on the ant-free tree. Field experiments show comparable results.

In this particular grove (the Walker orange grove, El Toro, California), which is in general under satisfactory natural control, the gray field ant was feeding on aphid honey dew, depressing populations of natural enemies, and thereby maintaining high average aphid populations as well as heavy coincident infestations of the California red scale. The poor state of the tree is mainly a result of red scale injury.

Ants and California Red Scale.—Comparative data from another grove (Sullivan lemon grove, Santa Barbara, California) involving biological check (Argentine ant-infested) trees and natural-control (ant-free) trees are presented in table 1. California red scale developed in this grove as a major pest coincident with ants tending mealybugs and soft scales. Red scale populations during 1950 averaged about 7 times as high on ant-infested trees as on ant-free trees. In November following the peak seasonal increase in scales, there were about 150 times as many red scales on the ant-infested trees as on the ant-free trees. These comparisons present a valuable indication of the efficacy of the natural enemies, both parasites and predators, of the California red scale. It is evident that ants do not eliminate natural enemies; they merely reduce their effectiveness in proportion to the number of

[5] In very heavy soft scale, mealybug, or aphid infestations, the removal of honeydew by ants may save many young from being "drowned."

Table 1.—Relative populations of the California red scale and its principal natural enemies on ant-free and ant-infested trees; Sullivan Lemon Grove, Santa Barbara, California, 1950.

Plot	Average California Red Scale Population Density[1]	Average Percentages Parasitization by *Aphytis* spp.[2]	Average Number of Predators[2]		
			Lindorus lophanthae	*Chilocorus* Sp.	Total
Natural-control plot (ant-free trees)	0.3	49.7	42	185	227
Biological check plot (ant-infested trees)	47.0	35.3	80	33	113

[1] At peak of seasonal scale increase. For the year, scale populations averaged about seven times heavier on the ant-infested trees than on ant-free trees.
[2] For first 6 months of 1950.

ants present. Normally, in view of the much heavier scale populations on the ant-infested trees, it might be expected that parasitization would be higher and predators would be more abundant on these trees than on the more lightly scale-infested, anti-free trees. The fact that this is not the case emphasizes the differences shown in table 1.

Another fact of interest shown in table 1 is that ants affect various species of natural enemies differentially. Although the total number of predators was reduced on the ant-infested trees, *Lindorus lophanthae* (Blaisd.) actually was present in greater numbers than on ant-free trees. This was probably because ants have less effect on *Lindorus* than on *Chilocorus* or *Aphytis* spp. and there is consequently less competition for *Lindorus* along with a higher density of hosts.

Ants and Honeydew Producers.—The ants in the Sullivan grove were feeding principally on honeydew secreted by the citrus mealybug, *Pseudococcus citri* (Risso), and the soft (brown) scale, *Coccus hesperidum* Linn., and were, of course, protecting them from their natural enemies. Relative populations of these two insects at the 1950 seasonal peak, on ant-infested and ant-free trees, are shown in table 2.

Table 2.—Relative populations of the citrus mealybug and the soft (brown) scale on ant-free and ant-infested trees; Sullivan Lemon Grove, Santa Barbara, 1950.

Plot	Number of Colonies per Tree[1]	
	Citrus Mealybug	Soft (Brown) Scale
Natural-control plot (ant-free trees)	2	0
Biological check plot (ant-infested trees)	52	16

[1] Based on the number of colonies observed in 5 minutes' searching; estimated population, 50 to 100 individuals per colony.

Ants and the Citrus Red Mite.—Another illustration of the use of the biological check method is afforded by a comparison of citrus red mite populations on ant-infested and ant-free trees in the Hardison lemon grove at Santa Paula (Table 3). The ants interfered with predators of the citrus red mite to such an extent that at the peak of infestation about 10 times as many mites were present on the ant-infested tree as on the ant-free tree. Such differences in citrus red mite populations have been observed in nearly every field test involving the presence and absence of ants.

Conclusions.—The experimental data indicate that the biological check method may be a valuable aid in measuring the efficacy of natural enemies of various plant pests. Although this method does not measure the total destruction accomplished by natural enemies, because they are not completely eliminated, the more abundant the ants are, the more accurate this method will be.

Fluctuations in populations of ants,

Table 3.—Relative populations of the citrus red mite on ant-free and ant-infested trees; Hardison Lemon Grove, Santa Paula, California, 1950.

Plot	Number of Citrus Red Mites			
	Oct. 27	Nov. 3	Nov. 16	Nov. 24
Natural-control plot (ant-free trees)	26	19	25	17
Biological check plot (ant-infested trees)	56	203	213	69

pests, and natural enemies may, of course, result from seasonal changes as well as from biotic interactions. Such fluctuations could at times, especially if ant populations drop, result in fewer natural enemies or more pest individuals on ant-free trees than on ant-infested trees. This would occur infrequently and could always be interpreted if adequate previous population data were taken.

SUMMARY.—Various methods of evaluating the effectiveness of natural enemies in the control of their hosts are reviewed. The use of honeydew-feeding ants to suppress natural enemy populations is suggested as a new method of evaluating the efficacy of natural enemies in the control of their host populations. Comparisons are made between pest and natural enemy populations on natural-control (ant-free) trees and on biological check (ant-infested) trees. Differences between the two indicate in part the effectiveness of the natural enemies. The degree of accuracy of this method depends upon the intensity of ant activity. Data show that ants may cause increases in diaspine scale and mite populations, in addition to their well-known effects of increasing populations of honeydew-secreting Homoptera. Ants are shown to depress populations of both parasites and predators of the California red scale. Certain species of natural enemies are shown to be affected more adversely than others by ants.

LITERATURE CITED

DeBach, Paul, 1946. An insecticidal check method for measuring the efficacy of entomophagous insects. JOUR. ECON. ENT. **39**(6): 695–7.

DeBach, Paul, E. J. Dietrick, and C. A. Fleschner. 1949. A new technique for evaluating the efficiency of entomophagous insects in the field. JOUR. ECON. ENT. **42**(3): 546–7.

Flanders, Stanley E. 1945. Coincident infestations of *Aonidiella citrina* and *Coccus hesperidum*, a result of ant activity. JOUR. ECON. ENT. **38**(6): 711–2.

Horton, J. R. 1918. The Argentine ant in relation to citrus groves. U. S. Dept. Agr. Bul. **647**: 1–73.

Newell, Wilmon, and T. C. Barber. 1913. The Argentine ant. U. S. Dept. Agr. Bur. Ent. Bul. **122**.

Smith, Harry S., and Paul DeBach. 1942. The measurement of the effect of entomophagous insects on population densities of their hosts. JOUR. ECON. ENT. **35**(6): 845–9.

Woglum, R. S., and A. D. Borden. 1921. Control of the Argentine ant in California citrus orchards. U. S. Dept. Agr. Bul. **965**.

Boll Weevil Infestations and Control in Eastern Arkansas in 1950[1]

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The boll weevil presents a varied problem in Arkansas. Hill areas ordinarily have heavier early infestations than delta areas. Infestations decrease in severity as one goes from south to north, because of colder winter weather and a shorter growing season. Dry summer weather is an effective control and may be locally important in outbreak years. Infestations vary from field to field, or even within fields, because of proximity to hibernation quarters and age and vigor of cotton.

This paper is based on infestation records on several hundred fields in the delta section of eastern Arkansas showing the extent of variations in infestations and the adaptations of control measures to the varying situations. The records were made weekly by eight cotton scouts in the regular performance of their duties. One was employed by Pulaski County to further the County Agents' educational program in weevil control.[3] Six of these men were employed by groups of cotton farmers to keep regular records of the changing infestations in their fields.[4] The eighth scout[5] was employed by the Regional Laboratory of the U. S. Bureau of Entomology and Plant Quarantine at Tallulah, Louisiana, to make infestation records in six counties of southeastern Arkansas. He had scouted this area for

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eight successive seasons. The work of all of the first seven of these men was in direct cooperation with the Arkansas Agricultural Extension Service.

This report does not concern itself with bollworm, red spider, and aphids. All of these were of considerable importance and were controlled as needed.

VARIATIONS IN INFESTATION.—The year 1950 was one of unusually widespread and heavy boll weevil infestation. Despite this situation early season infestations were heavy in only a few fields throughout the Mississippi-Arkansas-White river delta of eastern Arkansas. Variations in infestation were striking during June and July. The degree of variation is shown by records of which the following will serve as examples.

In 60 fields at Holly Grove, Monroe County . . . the maximum infestation on August 3, just prior to emergence of second generation weevils, was less than 25 per cent punctured squares. Eight fields had received a single application for control of overwintered weevils, and 31 fields had received one or two dusts, mostly spot treatments, for control of first generation weevils.

In the Elgin community of Jackson County in the field with the least infestation, weevil activity was at a low level with only one dust application required before August 11. From July 6 until August 11 maximum percentage of punctured squares was 15 and the average was 6. In the most heavily infested field six applications barely gave commercial control with a maximum of 50 per cent punctured squares and an average of 27. Extreme variations were found on each of two plantations in Pulaski County. On the one hand, Young No. 1 was a field of early cotton with 1620 weevils to the acre on June 22. Twelve applications, 6 each of calcium arsenate and 3–5–40, were made between June 22 and August 25, holding infestations between 14 and 34 per cent punctured squares. By contrast Young No. 3 did not require its first application until August 10 when the infestation rose to 31 per cent. Only two more applications were required to give excellent control through August.

On the second plantation Kitchens No. 3 was early cotton, presumably subject to heavy infestation. It was sprayed 10 times with dieldrin from May 20 to August 19. Infestation was low until July 28 when it rose to 41 per cent. Subsequent weekly counts were 46, 42, 90, and 86 per cent. By contrast, another field on the same farm was uninfested until August 4. This applied to the bulk of the field receiving four dieldrin sprays and to an untreated check area.

In the six southernmost delta counties in Arkansas (Jefferson, Lincoln, Drew, Ashley, Desha, and Chicot) infestations were unusually heavy and widespread in 1950, as shown by records for eight successive years. Even so, several fields were lightly infested through July, the period of first generation activity. Maximum infestations in different fields during July ranged from 1 to 100 per cent. Fields received from none to eight applications of insecticides during May, June, and July. There was no correlation beteeen number of treatments and infestation, showing that variations in infestation were of greater importance than insecticidal treatment.

EFFECT OF TIME OF PLANTING ON INFESTATIONS.—It is generally recognized that weevils are attracted to the largest and earliest cotton. Scouting records made in 1950 support this.

When scouting began the middle of June, fields at Tuckerman, Jackson County were classified as "early" and "late". In 36 fields classified as "early" the average infestation on July 27 was 12 per cent and the maximum was 36 per cent punctured squares. Thirty-two field applications, an average of almost one per field, had been made. In 29 fields classified as "late" the average infestation on July 27 was only 3 per cent and the maximum 13 per cent. Only one field had been dusted.

At Clarendon, Monroe County 29 of 33 fields of early cotton were infested by August 3. Only six out of 30 fields of late cotton were infested by this date.

EARLY TREATMENTS AND SUBSEQUENT INFESTATIONS.—Early treatments did not lower subsequent populations to a sufficient degree to reduce greatly the need for later control measures.

The Young and Valentine plantations in Pulaski county are adjacent and are similar in exposure to early weevil infestations, soil fertility, and management practices. In June three applications were made on all eight fields on the Valentine

plantation and a fourth was made on one field, table 1. Only one application was made on one field in June on the Young plantation. Later control practices were almost identical on the two farms and satisfactory control was obtained. During the first half of August infestations were lower on the Valentine plantation, indicating a possible reduction in weevil numbers from the early applications. Infestations during the last half of August were practically the same on the two plantations.

Table 1.—Effect of early treatment on subsequent infestations. Pulaski County, 1950.

Date	Per Cent Infestation	
	Young (five fields)*	Valentine (eight fields)
July 27–28	15	8
Aug. 3–4	21	8
10–11	21	6
17–18	16	20
24–25	29	27
June	0.4	3.12
July 1–23	0.4	0.25
July 24–Aug. 25	5.0	5.25
Total	5.8	8.62

A very light infestation can build up to damaging proportions during the course of two generations. This probably explains failure of early season control measures to give season-long protection. For example, in 63 fields at Clarendon during July maximum infestation was 25 per cent punctured squares, and 28 fields showed no infestation at all. However, all fields required control measures during August and early September. On August 24 in fields of early cotton the percentage of punctured squares generally ranged from 20 to 50 and these fields were on regular dusting schedules. In 19 fields of late cotton punctured squares ranged from 4 to 35 per cent with an average of 13 per cent. Four of these fields were being dusted. On September 7 dusting was being discontinued in early cotton because it was mature. Mass migration had occurred in some instances. In late cotton, infestations ranged from 15 to 40 per cent. Blooming had about stopped. Fields of late cotton were being dusted as weather permitted and continued applications for boll protection were needed.

Infestations at Marked Tree, Poinsett County, were extremely light early in the season. The maximum average on any farm did not exceed 10 per cent punctured squares through July. During August eight farms required applications on a regular schedule, two farms required regular applications on some of the fields, and five farms required no applications.

Importance of Late Season Control.—Application of insecticides in August and early September for control of second generation weevils was the most important step in boll weevil control in 1950.

During the first 19 days of August, when not more than two applications were made in the fields, the infestation on August 19 was 87 per cent in the six southern delta counties. When three or four applications were made, infestations averaged only 32 per cent, despite rainy weather.

Different schedules of application and different combinations of insecticides were applied for boll weevil infestations to 11 fields rather uniformly subject to heavy infestation on Fourche Island, Pulaski County, in the period from July 17 to August 31.

Nine applications of toxaphene dust, 20 per cent, in one field showed from 1 to 14 per cent punctured squares by August 28, the average being 5 per cent;

Nine applications of calcium arsenate alternated with a 3–5–40 mixture of 3 per cent gamma benzene hexachloride, 5 per cent DDT and 40 per cent sulphur showed from 6 to 36 per cent punctured squares with an average of 17 per cent in 3 fields;

Twelve applications of calcium arsenate alternated with the "3–5–40" mixture in two fields showed a range of from 9 to 38 per cent infestation, averaging 23 per cent but it should be noted that the fields given 12 applications were earlier than the others.

Five or six applications in four fields showed infestations ranging from 19 per cent to 55 per cent and averaging 38 per cent. Calcium arsenate, the "3–5–40" mixture, and a mixture of 2.5 per cent aldrin, 5 per cent DDT and 40 per cent sulphur were used in these four fields.

A spray containing 4 pounds toxaphene and 2 pounds of DDT to the gallon, applied five times, showed as high as 95 per cent punctured squares with an average of 72 per cent punctured.

Dusts were applied at 10 to 15 pounds

to the acre, usually by airplane. The spray was applied with a tractor-mounted sprayer and the amount of concentrate to the acre was not recorded.

MIGRATION.—General migration did not occur until cotton almost ceased to square, although, based on past experience, general migration was expected about the middle of August. None of the scouts reported migration during August and this is supported by general observations by the author and others. The only scout working beyond August 31, reported mass migration on September 7 at Clarendon. At this time early cotton was mature in the area he was scouting.

USE OF FEEDING PUNCTURES IN TIMING.—Timing of dust applications was determined by presence of feeding punctures and live weevils rather than percentage of total punctures in the cotton at Macks, Arkansas. This followed the spot dusting principle developed by Isely (1926). With the precise timing that was practiced, infestation counts were kept at very low levels despite high populations of overwintered weevils and favorable weather for weevil development. Although dusts were applied with low percentage counts, they were well-timed and there was little over-dusting.

In 6 of the 11 fields 1 to 3 spot dusts were made. In addition 3 to 12 blanket applications were made in all fields. General dusting began July 12 in 3 of the heaviest infested fields. In a field of late cotton the first application was made August 18. The last recorded application in all fields was August 25–28, although dusting was continued for boll protection in September.

Treatments kept infestations at low levels. Prior to August 31 maximum infestations in the 13 fields were 9 to 20 per cent. On August 31 infestations ranged from 8 to 30 per cent.

SUMMARY.—Boll weevil infestations were extremely variable in eastern Arkansas during early summer of 1950. During June and July early planted cotton was more heavily infested than later cotton. Infestations build up to high levels in August in all areas under consideration, including areas with extremely light early infestations. Despite heavier infestations by overwintered and first generation weevils, control was easier in early cotton because it required a shorter period of protection from weevils of the second and later generations.

Early season application of insecticides did not reduce later infestations sufficiently to reduce the necessity of control measures, later in the season. Regular applications of insecticides were necessary to keep heavy infestations under control late in the season. Where they were so applied, control was excellent and migration was prevented almost completely.

Timing applications by presence of feeding punctures and live weevils held infestations at low levels without wasting insecticides.

LITERATURE CITED

Isely, Dwight, 1926. Early summer dispersion of boll weevil with special reference to dusting. Ark. Expt. Sta. Bul. 204.

Control and Eradication of Pest Thysanurans

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There are four species of pest thysanurans in the United States, the common silverfish, *Lepisma saccharina* L., the four-lined silverfish, *Ctenolepisma quadriseriata* Pack., the gray silverfish, *C. urbana* Slabaugh, and the firebrat, *Thermobia domestica* Pack. (Sweetman & Kulash 1944). The food habits of these species are very similar. A wide variety of foods is eaten. They feed on many carbohydrate materials, but those containing protein are preferred to those consisting of starch alone. They often feed on dead insects, fungi, and similar foods rich in protein. Feeding damage to bookbindings, wallpapers, starch pastes, sized papers and starched and synthetic fabrics is most conspicuous in homes.

These pests are exceedingly difficult to eradicate from buildings, although a number of insecticides are effective in reducing heavy populations when properly applied. Useful insecticides include pyrethrum, DDT, chlordane, and lindane. Repeated applications of dusts or sprays over extended periods of time are essential to deplete heavy populations of these pests. The use of poison baits is likewise a very slow and tedious method of reducing thysanuran populations (Wakeland & Waters, 1931). Fumigation with HCN or other gaseous insecticides will deplete populations, but eradication is seldom obtained even with repeated applications. Moreover, the use of such toxic gases in habitations of man is not recommended because of the cost, inconvenience, and hazards involved. Repeated and thorough treatments with DDT dust over a period of two years failed to eradicate a heavy infestation of the common silverfish from a residence. Annual spring treatments in another residence with DDT from basement to attic for five successive years failed to eradicate the four-lined silverfish. The population was reduced for a time but soon increased to appreciable numbers. However, the common silverfish in this same residence appeared to have been eradicated after the third year. These applications were applied as preventive treatments with success against clothes moths and carpet beetles. The latter gain entrance to all homes in this region annually and evidence of their presence can be found in all homes not receiving preventive treatments.

A new method of application of insecticides,[1] *i.e.* automatic and continuous vaporization of minute quantities of the toxic agent over long periods of time shows much promise for eradication of pest thysanurans. Lindane was used in these tests, but other insecticides might be used also. Minute amounts of lindane may be vaporized which will destroy the insects with no apparent hazard or inconvenience to occupants of buildings. The method is practically odorless and does not stain.

METHODS AND MATERIALS.—Both field and laboratory tests were made. The field experiments were conducted in buildings at the University of Massachusetts. In some instances only partial treatment of buildings was attempted, hence migration from untreated portions of the buildings occurred. Repeat tests were made in several of these buildings upon the reappearance of the insects. Lindane was applied as a spray and as a vapor for comparative purposes (Table 1). DDT was applied as a spray and dust. Comparable amounts of lindane as vapor or spray were used in buildings of approximately equal arrangement and size. Similar treatments were made with DDT spray, lindane spray, and lindane vapor for comparison. All spray treatments were applied to selected areas as baseboards, pipes, heating units and other favorable places of congregation of the insects.

Observations were made at frequent intervals, oftentimes tri-weekly. The degree of infestation (Table 1) was based on three observations prior to treatment. The number of dead and living insects was recorded at each observation. The disappearance of the firebrats following treatment was determined by the day on which the last dead insect was observed.

Methods for rearing and handling of thysanurans in the laboratory have been described (Sweetman 1938). For testing

[1] The Aerovap System, Manufactured by American Aerovap, Inc. New York City.

Table 1.—The effectiveness of lindane spray and vapor treatments against firebrats, *Thermobia domestica* Pack.

Test No.	Building & Volume Cu. Ft.	Vaporization Days & Gms./ 20,000 Cu. Ft./Day	Spray. Gms. of Insecticide	Degree of Infestation	Days to Disappear	Days to Reappear	Observed Mortality
1	DB[1] 8,550	14 3.50	—	50–100	21	26	582
	DB 7,546	— —	20.0	50–100	16	14	489
2	DB 7,546	14 2.94	—	1–10	22	38	37
	DB 8,550	— —	20.0	10–25	40	21	137
3	AHB[2] 8,618	14 3.25	—	50–100	24	24	884
	AHB 8,330	— —	20.0	50–100	21	5	1,188
4	AHB 8,330	14 2.69	—	10–25	38	14	129
	AHB 8,618	— —	20.0	10–25	40	8	88
5	DB 27,548	— —	28.3	50–100	Failed	—	1,069
	DB 27,548	76 1.38	—	25–50	69	93	414
6	DB 27,548	76 1.38	—	25–50	69	93	414
	DUP[5] 91,800	34 1.60	—	25–50	20	70	651
	D[3] 100,350	— —	112.2	25–50	22	96	528
7	CR[4] 192,092	— —	566.3[6] 113.3[6]	25–50	40	95	331
	CR 136,800	178 0.81	—	25–50	30	[7]	508

[1] *DB* indicates dormitory basement.
[2] *AHB* apartment house basement.
[3] *D* dormitory.
[4] *CR* class room building.
[5] *DUP* dormitory upper floors.
[6] Spray and dust applications of DDT.
[7] No reappearance after 178 days.

purposes 30 individuals, 10 males, 10 females and 10 nymphs were transferred to a clean pan containing food and shelter. Three replications with 30 firebrats each were used for each experiment. A dormitory basement which had previously been infested with firebrats was used for the tests. A vaporizer with lindane was installed and the pans placed at distances of 10, 20 and 30 feet from the vaporizers. Mortality was recorded daily (Table 2).

RESULTS.—The relative effectiveness of lindane spray and vapor applications is compared in tests 1 to 4 (Table 1). The reappearance of the insects was delayed about twice as long following the vapor application as following the spray treatments. It is suggested that this delayed reappearance of the insects was a result of more complete elimination due to the penetration of the vapor into harborages of the pests rather than residual deposit. Comparable numbers of dead insects were recorded from both spray and vapor treatments, a total of 1902 for the former and 1632 for the latter.

In test 5, the basement was first sprayed with lindane which failed to eliminate the pests, although 1069 dead were observed over a period of 47 days. This basement was in use and was cleaned and mopped several times following the application. This spray deposit in a few undisturbed surfaces exhibited long-time residual kill. After reinfestation in the basement was well established, it was treated with lindane vapor. The basement was divided into five rooms separated by fire walls and doors. The vaporizer was transferred from room to room every few days. Disappearance of the firebrats was much delayed during this procedure, during which time 414 dead insects were observed. Since the entire building was treated with lindane vapor, migration

Table 2.—The effectiveness of lindane vapors against firebrats, *Thermobia domestica* Pack., under caged conditions.

Test No.	Days Exposed	Lindane Gm./20,000 cu. ft./day	Percentage Mortality Nymph	♂	♀
1	5	1.69	100	100	100
2	4	1.52	100	100	100

from the upper floors was reduced to a minimum (Test 6). The vapor treatment of this dormitory with lindane was comparable to treatment of a similar dormitory by a spray application. There was little difference in the results other than the delay mentioned previously in disappearance of the insects from the basement.

Two comparable class room buildings were treated with DDT and lindane (Test 7). The DDT was applied as a spray and dust, the latter on shelves and drawers where a spray application was not desirable. The lindane was applied from vaporizers. It is apparent that lindane vapor was more effective than DDT spray and dust, preventing reappearance of firebrats for a much greater period. It is thought that the more uniform dispersal and penetrating capacity of the vapor is accountable for this.

Adults and nymphs of both sexes were equally susceptible to the lindane vapor in laboratory tests (Table 2). Distance of the cages from the source of vaporization did not influence the time or percentage of mortality suggesting that lower dosages could be used. Eggs laid by the females during exposure, when placed in favorable environment, appeared unharmed. Normal percentages (Sweetman 1938), over 90 per cent, hatched.

DISCUSSION.—The circumstances under which most of the tests were conducted prevented continuation of vapor treatments over extended periods of time to determine if eradication could be effected. Test 7 is being continued to determine the feasibility of eradication. At present 178 days have elapsed without reappearance of the insects. The continuous evolution of minute quantities of lindane vapors over an extended period should prevent reinfestation and gradually eradicate the thysanurans. These and other tests suggest that residual deposits accumulate very slowly from vaporization of minute amounts of lindane. Meanwhile structural pests, other than wood pests, will be eradicated or prevented from becoming established.

The application with lindane appeared to exert some repellency to the firebrats. Immediately following treatments, the insects apparently become more active and hence more noticeable to occupants of the buildings. Similar activity was not noticed following applications of DDT.

There was little odor associated with either DDT or lindane vapor treatments. However, the odor from lindane spray applications was more noticeable to occupants.

The possible hazards to man from continuous vaporization of lindane in insecticidal concentrations seem slight. Toxicity tests, being published separately, with tropical fish, canaries, pigeons, chickens and rats suggest the method is relatively safe.

CONCLUSION.—Firebrats are highly susceptible to minute amounts of lindane vapor. Apparently continuous dispersal of the vapor penetrates harborages of the insects and offers a very effective method of control and probable eradication of these and other household pest thysanurans.

LITERATURE CITED

Back, E. A. 1939. Silverfish. U.S.D.A. Leaf. **149.**

Sweetman, Harvey L. 1938. The physical ecology of the firebrat, *Thermobia domestica* (Packard). Ecol. Monog. **8:** 285–311.

Sweetman, Harvey L. and W. M. Kulash. 1944. The distribution of *Ctenolepisma urbana* Slabaugh and certain other Lepismatidae. JOUR. ECON. ENT. **37:** 444.

Wakeland, C. and H. Waters. 1931. Controlling the firebrat in buildings by means of poisoned bait. Idaho Agr. Expt. Sta. Bul. **185.**

Tests of Lindane and Other Insecticides for Control of *Lygus oblineatus*

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The "*Lygus* complex" of plant bugs pose a cosmopolitan problem, ranging in importance with different crops and habitats, from an annoying pest to a limiting factor in production. Many attempts at working out control measures have been essayed since Harris (1861) first called attention to the true nature of the tarnished plant bug. Practically all control attempts were palliative rather than positive prior to the advent of the chlorinated hydrocarbons (DDT *et seq.*). Since 1941 various reports indicate that probably several of the newer insecticidal chemicals are effective and usable against tarnished plant bug under conditions peculiar to given crop infestations. The problem may be simply stated as that of finding the material which will economically control Lygus without secondary complications such as taste, discoloration and poisonous residues.

From 1948 to 1950 studies were made at Michigan State College, East Lansing, on the biology and control of the tarnished plant bug, *Lygus oblineatus* (Say). Lindane and thirteen other insecticides (Table 1) were used in the greenhouse tests.

Five insecticides were tested in the field for the control of *Lygus oblineatus* on Chinese cabbage. Lindane was tested separately on celery, under controlled field conditions, in view of its longest residual effect and high percentage of mortality. The experimental work on celery was set up on a split plot design to correlate the effect of concentration of insecticide, number of applications, and intensity of infestation on control of *L. oblineatus*.

PROCEDURE.—1. In the greenhouse, Chinese cabbage, *Brassica pekinensis* var. michihli, was used as test plant. The potted test plant was placed for 40 seconds at the center of a turntable revolving at the rate of 14 revolutions per minute. The insecticide was applied from an atomizer type spray gun, adjusted to 20 pounds pressure, controlled by a DeVilbis pressure regulator valve. The sprayed plants were set aside for drying before they were put under the cages and 10 tarnished plant bugs were released in each cage. Water sprays were included to serve as checks. Mortality counts of tarnished plant bugs were made every twenty-four hours. All tests were replicated three times and the whole experiment was repeated once.

Table 1.—Concentrations of insecticides used as contact spray for the control of L. oblineatus.

No.	Insecticide	Per Cent Active Ingredient	Ounces per 100 Gallons		
			High Concentration	Medium Concentration	Low Concentration
1	Nicotine Sulfate	40	32	16	8
2	Nicotine Sulfate + Pyrethrum + Sulfur	40 18 95	24 32 96	12 16 48	6 8 24
3	Rotenone	4	160	80	40
4	Ryania	40	480	240	120
5	Methoxychlor	50	64	32	16
6	DDT	50	64	32	16
7	TDE	50	64	32	16
8	Toxaphene	40	64	32	16
9	Chlordane	40	64	32	16
10	Lindane	25	32	16	8
11	Parathion	15	32	16	8
12	TEPP	50	32	16	8
13	Pestox 3	66	32	16	8
14	Allethrin	4	32	16	8

Certain of the insecticides giving high initial mortality were tested for residual toxicity by releasing fresh batches of bugs every twenty four hours and recording the mortality.

2. A randomized block experiment, for the control of *Lygus oblineatus* on Chinese cabbage by lindane, parathion, TEPP, and nicotine sulfate+pyrethrum+sulfur, was set up at the Michigan State College Muck Experimental Farm. A plot 25 by 20 feet was divided into five subplots. Each subplot consisted of two rows of Chinese cabbage, each row having 17 plants. The distance was 25 inches between rows and 15 inches between plants in the row. The treatments were completely randomized and were replicated six times.

Chinese cabbage was planted on July 1, 1950, and was sprayed, with a 3-gallon compressed air sprayer operated at a pressure of 32 pounds, on July 16, July 26,

[1] The author, a graduate student from Pakistan, is indebted to Professor Ray Hutson and other members of the Entomology Department for counsel and help in this work, which formed a part of Ph.D. dissertation.

and August 5, 1950. Four plants were pulled at random from each subplot on August 6, 1950, and the total number of feeding punctures was recorded. No further data was collected as a hail storm completely ruined the crop on August 7.

3. The controlled field experiment on celery was also conducted at the Muck Experimental Farm. Due to low infestation of *L. oblineatus* in that area, large cages, 20×30×6 feet, were constructed in order to establish uniform infestations. Each cage was divided into nine compartments. A compartment contained four rows of celery with ten plants in each row. One row of celery in each compartment served as a check; the other three rows were randomized for the three schedules of spray, 2, 4 and 6 applications. The three concentrations of lindane (low, medium, and high), and the three intensities of infestations (A, B, and C representing 200, 400, and 800 tarnished plant bugs respectively) were randomized in the nine compartments on a "latin square" arrangement. Three replicates were used in this experiment.

Celery (*Apium graveolens*, variety Cornell 19) was transplanted into the cages on June 10, 1950. Dithane was used as a fungicide on July 31, 1950. Lindane was applied with a three-gallon compressed air sprayer operated at a pressure of 32 pounds. The tarnished plant bugs were not introduced into the cages all at one time but were released in batches on the dates corresponding to the observed peaks of infestations in the field. These peaks were ascertained from the data on seasonal variation in the population of *Lygus oblineatus* for the years 1948 to 1950 (Fig. 1). The schedule of sprays and the different concentrations in terms of amount of insecticide used per acre per application are given in table 2.

Preliminary observations were made on August 16, 1950 by recording injury on one plant pulled at random from each row. The crop was harvested on September 15, 1950.

OBSERVATIONS AND DISCUSSION.—*Experiment 1.*—It is apparent from the data (Table 3) that natural organic insecticides are relatively ineffective for the control of *Lygus oblineatus*. Nicotine sulfate plus pyrethrum plus sulfur gave but 24.6 per cent net mortality at high concentration

Table 2.—Schedule of sprays and the amount of insecticide used for control of *Lygus oblineatus* on celery.

DATE			AMOUNT OF LINDANE 25%, IN OUNCES, USED PER APPLICATION PER ACRE CONCENTRATION		
2 Sprays	4 Sprays	6 Sprays	Low	Medium	High
6/29	6/29	6/29	11.6	23.2	46.4
—	7/18	7/12	11.6	23.2	46.4
—	—	7/26	15.4	30.8	61.6
8/7	8/7	8/9	17.4	34.8	69.6
—	8/27	8/23	19.3	38.6	77.2
—	—	9/7	23.2	46.4	92.8

thus confirming the findings of Sorensen (1942) that there was no significant advantage of the treatment over the control. A control of 80 to 85 per cent reported by Smith & Scales (1937 and 1939) might have been due to the repellent action of sulfur at higher temperatures.

Rotenone and ryania proved to be delayed action insecticides. The bugs remained in a moribund condition for a long period before being killed. Shull (1944) reported 49 per cent control with rotenone but this was not confirmed by the present tests. The concentration of ryania needed even to obtain L.D. 50 was too high to be practicable for field or truck crops.

Among the synthetic organic insecticides, methoxychlor, DDT, and TDE are structurally nearer each other than the rest of the hydrocarbons used in these tests. Methoxychlor gave no control whereas DDT and TDE gave a maximum control of 85.7 per cent. In order to obtain the same degree of control with DDT

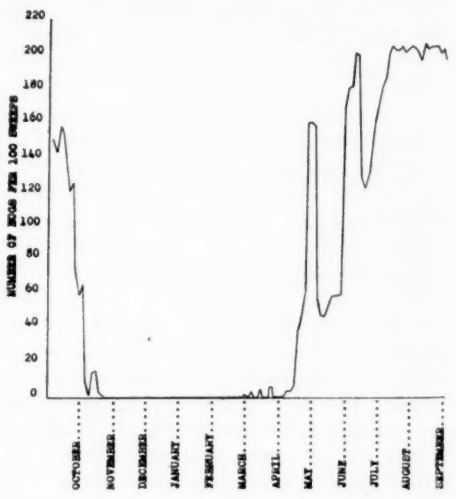

FIG. 1.—Seasonal variation in the population of *Lygus oblineatus*.

Table 3.—Per cent control by various insecticides as contact spray against *L. oblineatus*.*

Insecticides	High Concentration				Medium Concentration				Low Concentration			
	Hours After Spray				Hours After Spray				Hours After Spray			
	24	48	72	96	24	48	72	96	24	48	72	96
Nicotine Sulfate	6.7	20.0	26.7	42.9	0.0	20.0	26.7	40.0	6.7	13.3	20.0	40.0
Nicotine Sulfate+ Pyrethrum+Sulfur	0.0	15.0	23.3	24.6	0.0	8.3	8.3	8.8	0.0	0.0	5.0	7.1
Rotenone	0.0	0.0	0.0	5.3	0.0	0.0	6.6	—	0.0	0.0	3.3	6.6
Ryania	0.0	16.6	45.0	49.1	0.0	6.6	15.0	19.3	0.0	0.0	11.6	12.2
Methoxychlor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDT	13.7	26.3	75.4	82.1	17.2	43.8	71.9	85.7	8.3	29.7	59.1	66.0
TDE	63.9	69.7	83.9	85.7	46.6	53.4	64.6	73.2	35.2	43.1	55.3	—
Toxaphene	0.0	0.0	55.0	70.0	0.0	0.0	60.0	70.0	0.0	0.0	20.0	40.0
Chlordane	93.0	100.0	—	—	100.0	—	—	—	50.0	78.2	81.9	90.9
Lindane	96.6	100.0	—	—	96.6	100.0	—	—	100.0	—	—	—
Parathion	78.3	91.6	100.0	—	90.0	100.0	—	—	53.3	56.6	—	—
TEPP	100.0	—	—	—	91.6	—	—	—	55.0	—	—	—
Pestox 3	0.0	6.6	15.0	23.3	0.0	8.3	13.3	—	0.0	0.0	0.0	0.0
Allethrin	0.0	0.0	20.0	25.0	0.0	0.0	13.3	15.0	0.0	0.0	0.0	0.0

* All figures for per cent control are corrected against the untreated series using "Abbot's formula" (1925).
60 tarnished plant bugs were used in each test.

and TDE, the latter had to be applied at double the concentration. The increase in the concentration of DDT, from medium to high, did not increase mortality. DDT showed a residual effect for six days whereas TDE was effective for but five days.

Although it is not definitely decided which portion of the DDT molecule is toxic, it is clear from the above set of tests that the p-chlorophenyl groups play an important role in its insecticidal action. In methoxychlor the p-chlorophenyl groups are replaced by p-methoxyphenyl groups and as such it has no toxicity for *L. oblineatus*. According to Martin and Wain (1944) the toxic portion of the DDT molecule is the trichloroethyl group and the chlorophenyl rings provide lipoid solubility. It appears that the trichloroethyl group in methoxychlor is unable to impart its toxicity to *L. oblineatus* in the absence of the lipoid solvent. This theory is further strengthened by the results obtained from the application of TDE where apparently the decline in per cent control is due to the replacement of one cl-group.

The results with DDT were in accord with the results reported by Granovsky (1944) who found that one per cent and 2.5 per cent DDT dust gave similar control.

Toxaphene proved similar in effectiveness to DDT as regards the increase in concentration. Stearns *et al.* (1947) and Kelsheimer (1948) reported phytotoxic effects of toxaphene on cucumbers, cataloupes, and squashes. No phytotoxic effects were noticed on Chinese cabbage for tens days after spray.

Chlordane, 40 per cent wettable powder, at low concentration gave 50 per cent control for a period of 24 hours but by doubling the concentration, the per cent control also correspondingly doubled. Further increase in the concentration of chlordane did not make any appreciable difference in the residual toxicity of the insecticide. Scales & Smith (1948) found 20 per cent toxaphene dust superior to 20 per cent chlordane dust. In the case of wettable powders, however, 40 per cent chlordane proved much superior to 40 per cent toxaphene.

Lindane gave excellent results even at low concentration. It combined the two desirable qualities, immediate kill and long residual effect. At medium concentration the residual effect lasted for twelve days in August. In the earlier tests in May, the residual effect of lindane lasted for sixteen days with medium concentration but with high concentration it extended to one month. It may be pointed out that temperature might have played an important part in the retention of toxicity.

Parathion and TEPP proved excellent for immediate kill. TEPP gave 100 per cent control at high concentration but was ineffective three hours after application probably because of chemical breakdown. It is seemingly the best insecticide for

Table 4.—Influence of treatments on injury to Chinese cabbage by *L. oblineatus* as calculated from the number of punctures on the midrib.

Treatments	Amt/Acre /App. in Ounces	Replications 1	2	3	4	5	6	Mean
Untreated	—	62	55	50	45	52	49	52.2
Parathion 15%	36.9	22	30	25	29	28	18	25.3
Lindane 25%	24.6	13	17	11	24	22	14	16.8
TEPP 50%	24.6	26	23	20	27	25	34	25.8
Nicotine Sulfate + 40% Pyrethrum + 18% Sulfur 95%	18.5 + 24.6 + 73.8	25	26	43	25	32	41	32.0

cleaning heavy infestation of *Lygus oblineatus* near harvest time. Parathion is more stable although the residual toxicity is mainly dependent on temperature.

Pestox 3 and Allethrin treatments proved of no significant advantage over the check.

In the supplementary tests on the residual effect of insecticides at medium concentration, it was found that lindane was effective for 12 days, chlordane and DDT for 6 days, TDE for 5 days, parathion for 4 days, and TEPP for 2 to 3 hours.

Experiment 2.—A study of the data (Table 4) indicates that all the four treatments were significantly better than the untreated check.

Although TEPP loses toxicity quickly it gave as good control as parathion. This may have been due to the low infestation of the tarnished plant bugs. The bugs which were present at the time of first application were immediately killed by TEPP and new infestations did not build up readily. Before the new infestation produced extensive damage the plants were sprayed again.

Lindane proved significantly better than any other insecticide treatment. There was no significant difference between the other three materials tested.

Experiment 3.—The results of this experiment were based on the following quantitative criteria:

a. Yield.
b. Percentage of the injured celery stalks.
c. Total injury based on the number of feeding punctures on the stalks of celery.

The evaluation on the basis of yield was done by taking the total weight of plants in each row, before and after trimming, and the data was analyzed statistically.

Table 5 represents the actual data on the weight (in ounces) of nine celery plants, trimmed for marketing, harvested from each row. The analysis of variance of the data showed that there was no significant variation in the yield of celery as a result of difference in infestation or the concentration of insecticide. However, the number of sprays was significant at one per cent level. As compared to the check, the yield increased by 1.7, 5.3, and 2.2 tons per acre with 2, 4, and 6 applications respectively. There was no signifi-

Table 5.—Weight in ounces of nine trimmed celery plants harvested from plots treated with lindane.

Replications	Infestations	Low Concentration 8 Ounces per 100 Gallons — Number of Sprays 0	2	4	6	Medium Concentration 16 Ounces per 100 Gallons — Number of Sprays 0	2	4	6	High Concentration 32 Ounces per 100 Gallons — Number of Sprays 0	2	4	6
I	A	301	285	309	256	254	280	246	240	289	239	304	301
	B	228	258	271	214	316	330	383	303	277	267	362	350
	C	243	362	322	319	272	278	304	285	250	263	307	316
II	A	224	287	373	360	289	248	262	236	253	320	300	278
	B	296	253	246	289	295	300	348	313	255	280	287	269
	C	300	297	279	264	245	304	268	207	328	351	418	353
III	A	213	239	378	228	259	224	312	342	171	196	263	184
	B	268	315	325	339	169	241	255	317	244	201	276	197
	C	252	240	320	277	228	259	288	225	192	303	317	281
Total		2325	2536	2823	2546	2327	2464	2666	2468	2259	2420	2834	2529

Infestation A = 200 bugs per cage.
Infestation B = 400 bugs per cage.
Infestation C = 800 bugs per cage.

Table 6.—Percentage of stalks injured by feeding punctures of *Lygus oblineatus*, as related to the treatments.

Replications	Infestations	Low Concentratiln 8 Ounces per 100 Gallons				Medium Concentration 16 Ounces per 100 Gallons				High Concentration 32 Ounces per 100 Gallons			
		Number of Sprays				Number of Sprays				Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	34.5	44.4	27.3	14.3	38.5	44.4	28.6	8.0	37.9	40.0	7.2	0.0
	B	53.8	46.2	32.0	27.6	55.6	48.4	25.0	18.2	40.0	32.3	19.4	10.0
	C	50.0	53.3	40.0	32.1	40.7	33.3	25.0	25.0	33.3	57.7	30.0	17.2
II	A	34.3	28.1	14.3	10.5	39.3	26.1	20.0	18.5	28.6	23.1	7.2	3.8
	B	56.7	31.3	29.6	23.1	41.4	41.7	25.0	18.4	54.2	28.6	18.8	10.7
	C	66.7	35.7	32.1	20.8	53.6	34.6	25.0	30.8	62.5	48.6	22.9	12.2
III	A	34.8	32.3	22.6	7.4	33.3	29.6	18.5	7.7	23.8	25.0	9.1	0.0
	B	44.4	39.4	28.0	23.5	41.7	28.6	23.1	7.2	31.0	28.6	17.9	6.7
	C	48.0	37.9	34.5	29.6	43.8	35.5	26.5	10.3	37.5	31.6	23.8	12.0

cant difference between the yields from the plots receiving 0, 2, and 6 applications but was highly significant in plots receiving 4 applications. It appears that two applications of lindane stimulated growth of celery. This growth was increased with 4 applications but a depressing effect was noticed from six applications. It is also possible that the increase in yield was not due to a direct stimulating effect of lindane but a result of the reduction of *L. oblineatus* infestation on the crop. In this case it is assumed that lindane had an initial depressing effect on the growth of celery but whereas the plants came out of the shock in case of 2 and 4 applications due to longer intervals between successive applications, with six applications the interval was too short resulting in decreased yield despite the kill obtained on *Lygus oblineatus*.

The data discussed above represented the gross yield irrespective of the injury due to feeding punctures of *L. oblineatus* which affects the quality of celery and often becomes a major factor in its marketing. Random samples, consisting of 33 per cent of the celery harvested from each row, were analyzed for the percentage of injured stalks (Table 6) and the total number of feeding punctures on the stalks of celery (Table 7). An analysis of variance of the percentage of injured stalks showed that infestation, concentration, and number of applications were significant at one per cent level. High concentration of lindane was significantly better than medium concentration which was in turn significantly better than low concentration when average means of all the intensities of infestation were considered together. However, at

Table 7.—Feeding punctures on trimmed celery as influenced by treatments.[1]

Replications	Infestations	Low Concentration 8 Ounces per 100 Gallons				Medium Concentration 16 Ounces per 100 Gallons				High Concentration 32 Ounces per 100 Gallons			
		Number of Sprays				Number of Sprays				Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	145	133	76	20	108	155	74	36	190	104	11	0
	B	247	185	93	58	239	160	40	33	160	142	43	13
	C	155	181	92	64	163	127	75	45	153	225	78	38
II	A	110	79	29	24	94	60	48	30	66	69	7	4
	B	238	100	62	39	224	113	60	29	173	83	19	11
	C	293	104	83	54	220	83	65	49	331	136	60	20
III	A	87	87	38	7	97	68	37	8	76	58	14	0
	B	288	189	59	42	263	74	42	14	189	80	43	7
	C	408	171	93	89	280	142	77	24	191	104	69	28

[1] Computed on the basis of one hundred stalks.

high intensity of infestation (800 bugs per compartment) there was no significant difference between medium and high concentration although either was significantly better than low concentration.

On the basis of total means, the number of applications was highly significant. The amount of injury by *Lygus oblineatus* to celery stalks was least with six applications at high concentration. High concentration with four applications was as good as medium concentration with six applications.

The intensities of infestation also produced highly significant differences in the percentage of injured stalks. The analysis showed that for high intensity of infestation four applications of medium concentration were as good as six applications.

Almost similar results were obtained from the data on the total number of feeding punctures. All the three variables, concentration, infestation and number of applications, were highly significant. The injury due to feeding punctures sharply declined as the number of applications increased from two to four but this reduction followed the law of diminishing returns when the number of applications was increased from four to six. The same correlation held true with respect to the intensities of infestation.

All the analyses point to the conclusion that unless the infestation is extremely high, four applications of medium concentration will give a more satisfactory control taking into consideration both yield and quality. Under extremely high infestations it would probably pay to sacrifice extra yield and obtain better quality by increasing the number of applications to six.

A great objection to the use of BHC has been the off-flavor and off-taste which it imparts to many crops. Samples of celery were taken at harvest from rows which were treated with six applications of high, medium, and low concentrations of lindane and were tested by the Department of Food and Nutrition at Michigan State College. None of the testers reported any off-flavor or off-taste. The scores were based on the relative strength of the typical flavor of celery raised in this section of the country.

SUMMARY AND CONCLUSIONS.—A. Fourteen insecticides at three concentrations, low, medium, and high, (Table 1), were tested against the tarnished plant bug, *Lygus oblineatus* (Say), in the greenhouse.

Lindane, chlordane, and parathion gave 100 per cent control at high concentration. Tests on the residual effect of insecticides at medium concentration showed that during summer lindane remained effective for 12 days, chlordane and DDT for 6 days, TDE for 5 days, parathion for 4 days, and TEPP for 2 to 3 hours. TEPP appears to be a good insecticide for cleaning heavy infestations of *L. oblineatus* just before harvest.

DDT gave 85.7 per cent net mortality at medium concentration but it required double the amount of TDE to obtain the same kill. Toxaphene ranked next in order but proved a delayed action insecticide. Toxaphene 40 per cent wettable powder, applied at the rate of 4 pounds per hundred gallons of water, did not produce any phytotoxic symptoms on Chinese cabbage.

Methoxychlor, Pestox 3, allethrin, and the natural organic insecticides proved relatively ineffective.

B. In the field experiment lindane proved significantly better than parathion, TEPP, and nicotine+pyrethrum +sulfur for the control of *L. oblineatus* on Chinese cabbage.

C. The effectiveness of lindane for the control of *L. oblineatus* on celery was tested in a controlled field experiment set up on a split plot design in order to evaluate the variations in concentration and the number of applications per season with respect to the varying intensities of infestation.

The number of applications proved highly significant. As compared to the check, there was an increase of 1.7, 5.3, and 2.2 tons per acre in the yield of celery with 2, 4, and 6 applications respectively.

Differences in the concentration of lindane and in the intensity of Lygus infestation did not produce any significant change in the gross yield of celery but were highly significant when evaluation was made on the basis of quality as judged from the percentage of injured stalks and the total number of feeding punctures.

For medium and moderately high infestations four sprays of medium concentration of lindane gave practical field control both with regard to yield and quality. For heavy infestations it is

desirable to sacrifice the extra yield and obtain better quality celery with six applications.

Celery treated with six applications of lindane at low, medium, and high concentrations did not give any off-flavor or off-taste.

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LITERATURE CITED

Abbot, W. S. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. **18**: 265–67.

Granovsky, A. A. 1944. Tests of DDT for the control of potato insects. JOUR. ECON. ENT. **37**: 494–9.

Harris, T. W. 1861. A treatise on some insects injurious to vegetation. Flint ed. Orange Judd Company, New York.

Kelsheimer, E. G. 1948. The control of insect pests of cucumber and squash. Market Growers Jour. **77**: 16 & 27.

Martin, H., Wain, R. L. 1944. Insecticidal action of DDT. Nature. **154**: 512.

Scales, A. L., and Smith, G. L. 1948. Cage tests against the Boll Weevil and the Tarnished Plant Bug with synthetic organic insecticides and calcium arsenate in 1947. JOUR. ECON. ENT. **41**: 403–5.

Shull, W. E. 1944. Idaho Agr. Exp. Sta. Bul. **236**: 45–46.

Smith, G. L., and Scales, A. L. 1937. Toxicity of a number of insecticides to three cotton insects. JOUR. ECON. ENT. **30**: 864–869.

Smith, G. L., Scales, A. L., and Gaines, R. C. 1939. Additional records on the effectiveness of several insecticides against three cotton insects. JOUR. ECON. ENT. **32**: 798–802.

Sorensen, C. J. 1942. Insecticidal tests for field control of Lygus bugs in seed alfalfa. JOUR. ECON. ENT. **35**: 884–6.

Stearns, L. A., *et al.* 1947. A chlorinated bicyclic terpene used to control certain fruit and vegetable insects. JOUR. ECON. ENT. **40**: 79–83.

A Modified Probit Method for Comparison of Insecticides for Wireworm Control

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The comparison of toxicity of two insecticides to wireworms necessitates the determination of mortality in relation to time and to concentratiou. A table listing the required concentration or dosage to give a certain mortality, perhaps the median lethal point, for a given period of exposure has proved to be of relatively little value because of the inherent differences in the various insecticides.

A series of tables giving the required concentrations to kill 10, 25, 50, 75, and 90 per cent of the test insects in a series of exposure periods ranging from a few minutes to several days will indicate this difference between two insecticides. Such a series of tables is difficult to read, however, and at best can give only a limited number of points for each concentration, time and mortality. The fact that it takes twice as much of A to kill 50 out of 100 wireworms in 2 hours of exposure as it does of B does not prove that A is only half as effective as B, except for 50 per cent mortality and 2 hours of exposure. Any other mortality level and any other exposure period would give different results unless the insecticides being tested were inherently more alike than most of those thus far tested.

Some means of visual comparison is very helpful. The simplest is a straight-line regression. This appears practical for wireworm studies, through the use of probits of mortality plotted against the logarithm of the product of the exposure period times concentration. Bliss (1934) developed the word "probit" as a contraction of "probability unit." It simplified the method previously used by other workers for converting a S-curve into a straight line when used with logarithms. He used this method to straighten out both the dosage-mortality curve and the time-mortality curve (Bliss, 1935, 1937). Finney (1947) combined the time and concentration as a single logarithm but plotted two lines. One of these lines represented variation in concentration at a

[1] Acknowledgment is made to M. C. Lane, under whose direction this work was done; to W. C. Cook for help on methods and statistical applications; and to E. W. Jones for use of field records.

Table 1.—Corrected mortalities in percentage of wireworms due to laboratory experiments.

Concentration		Dosage, Pounds	Periods of Exposure					
Per Cent	Parts per Billion	per Acre	15 Minutes	75 Minutes	5 Hours	24 Hours	4 Days	16 Days
			DDT (90° C. setting point)					
1.0	10,000,000	30,000	62	88	90	100	100	—
0.1	1,000,000	3,000	55	74	51	100	100	100
0.01	100,000	300	—	—	24	42	86	100
0.001	10,000	30	—	—	—	4	19	56
0.0001	1,000	3	—	—	—	—	21	61
			Aldrin					
1.0	10,000,000	30,000	100	100	100	100	100	—
0.1	1,000,000	3,000	39	100	100	100	100	100
0.01	100,000	300	73	84	96	100	100	100
0.001	10,000	30	—	38	47	91	99	100
0.0001	1,000	3	—	—	14	46	49	74
0.00001	100	0.3	—	—	—	35	48	39
0.000001	10	0.03	—	—	—	—	18	47
			Benzene Hexachloride (expressed as gamma isomer)					
0.1	1,000,000	3,000	100	100	—	—	—	—
0.01	100,000	300	91	100	—	—	—	—
0.001	10,000	30	—	62	100	—	—	—
0.0001	1,000	3	—	—	17	57	98	100
0.00001	100	0.3	—	—	—	—	56	65
			Toxaphene					
1.0	10,000,000	30,000	41	54	91	100	—	—
0.1	1,000,000	3,000	—	—	14	86	100	—
0.01	100,000	300	—	—	—	9	77	100
0.001	10,000	30	—	—	—	—	9	75
			Chlordane					
0.1	1,000,000	3,000	5	23	82	100	—	—
0.01	100,000	300	—	—	28	82	—	—
0.001	10,000	30	—	—	—	—	42	86
0.0001	1,000	3	—	—	—	—	—	14
			A Bromine analog of DDT (Colorado 9)					
1.0	10,000,000	30,000	—	—	5	5	61	—
0.1	1,000,000	3,000	—	—	—	—	10	29
			Parathion					
1.0	10,000,000	30,000	100	100	—	—	—	—
0.1	1,000,000	3,000	82	100	—	—	—	—
0.01	100,000	300	—	40	100	—	—	—
0.001	10,000	30	—	—	14	34	96	—
0.0001	1,000	3	—	—	—	4	16	14
0.00001	100	0.3	—	—	—	—	4	20
			Methoxychlor					
1.0	10,000,000	30,000	—	24	27	63	—	—
0.1	1,000,000	3,000	—	—	—	—	68	—
0.01	100,000	300	—	—	—	—	15	—

constant of time, the other variation in time with a fixed concentration.

The author has found that one line could be used to represent the product of time and concentration. This product provides a constant for any given mortality, and the constants for a series of mortalities provide points from which may be calculated a regression line, which is a measure of efficiency of the insecticide against wireworms and is also a ready and accurate estimate of the dosage to be tried in the field.

A series of laboratory tests of recently developed insecticides against wire worms (*Limonius* spp.) has been analyzed. A step by step method of probit analysis outlined by Finney (1947, Appendix I) was used to locate the points for the desired regression lines. Even when results with those

insecticides showing considerable scatter were plotted, there was no indication of curvature. It may be that for some insects a correction such as suggested by Bliss (1940, pp. 732–33) might be necessary; however, for wireworms such a correction does not appear to be necessary.

EXAMPLE.—A recent experiment with technical DDT (90° C. setting point) will serve as an example. Wireworms were held for different exposure periods in tin cans of soil that had been mixed with DDT at five concentrations. Ten wireworms were used in each can, and 10 cans were used for each exposure period for each concentration. Some of the tests were repeated with 10 additional cans. When the final results were available, the mortalities were corrected for those found for the wireworms held in untreated soil (table 1). This table than contains the information necessary for the probit analysis as outlined by Finney (1947) with the exception of the numbers of wireworms in each test and the check mortality.

The steps in the analysis correspond to the columns in table 2. The first column shows the logarithms of the concetrations in terms of parts per billion (one thousand million) in soil. (A 1-per cent concentration equals log 7.00, 0.1 per cent equals log 6.00. Parts per billion were used to avoid negative logarithms.) The next column shows the logarithms of the number of minutes of exposure. (Fifteen minutes equals the log 1.176, while 16 days (23,040 minutes) equals the log 4.362.) The third column, the x value of the analysis, shows the sum of the logs in the two preceding columns (Finney, 1947, pp. 105, 116–120). This is the logarithm of the product of the number of minutes of exposure time the parts per billion of concentration. The fourth column shows the probit based on the corrected mortality for that exposure and concentration. The next step is to draw a provisional straight line to fit the points when the probits of column 4 are plotted against the x values of column 3 (fig. 1). Where rough approximations are sufficient to provide the information or comparison desired, and the time for the calculations is not available, it is suggested that the provisional straight line be used instead of the calculated regression line. With experience this "eye-fitted line" will be very close (Wadley,

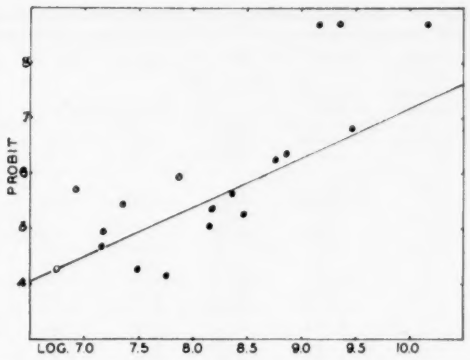

FIG. 1.—Distribution chart with visual regression line showing results of DDT tests against wireworms.

1945). Column 5 in table 2 shows the expected probit, Y, read from this provisional straight line. Column 6 shows n, the number of wireworms on which this record is based. If the same number of wireworms is used in each case, this column would be omitted and the n value listed at the head of the table. Column 7 is the nw value, obtained by multiplying the number of wireworms used (Column 6) by a weighting factor (Finney, 1947, Table II), which gives much the greater value or importance to those tests which approach the median lethal point. Here the check mortality (10 per cent) is also taken into consideration. A table of weighting coefficients is practically a necessity. Column 8 gives the y value, a correction read from another table (Finney, Table IV) to smooth out differences between the actual mortality obtained and the Y value read from the provisional straight line. Column 9 is the value when nw is multiplied by x. Column 10 is the value when column 7 is multiplied by column 8.

The next step suggested is to add the products of each nwx item (column 9) mutiplied by its corresponding y value (column 8); then add the products of each nwy item (column 10) multiplied by its corresponding x value (column 3). If the sum of one set of products differs from the sum of the other set by as much as 1, it will probably pay to check back on the multiplications which provide the items in columns 9 and 10. (This check is in addition to those listed in Appendix I of Finney, 1947.) If the difference is less than 1, the average of the two sums will serve as the value for $nwxy$ from which to sub-

Table 2.—Steps in probit analysis of results with DDT (90; C. setting point).

(1) Log of Concentration	(2) Log of Time	(3) x	(4) Probit	(5) Y	(6) n	(7) nw	(8) y	(9) nwx	(10) nwy
7	1.176	8.18	5.36	5.50	200	100.11	5.35	818.90	535.59
	1.875	8.88	6.34	6.10	200	71.72	6.3	636.87	452.55
	2.477	9.48	6.88	6.65	100	19.93	6.84	188.94	136.32
	3.158	10.16	8.72	7.25	100	7.52	7.63	76.40	57.38
6	1.176	7.18	4.90	4.60	200	90.81	4.91	659.20	450.79
	1.875	7.88	5.92	5.25	200	104.86	5.82	826.30	610.29
	2.477	8.48	5.23	5.75	100	45.20	5.14	383.30	232.33
	3.158	9.16	8.72	6.50	100	24.04	7.02	220.21	168.76
5	2.477	7.48	4.26	4.90	100	51.09	4.32	382.15	220.71
	3.158	8.16	5.03	5.50	200	100.11	4.98	816.90	498.55
	3.760	8.76	6.23	6.00	100	38.75	6.20	339.45	240.25
	4.362	9.36	8.72	6.55	100	22.65	7.05	212.00	159.68
4	3.158	7.16	4.64	4.60	200	90.82	4.64	650.27	421.40
	3.760	7.76	4.12	5.10	100	52.60	4.22	408.18	221.97
	4.362	8.36	5.64	5.65	100	47.37	5.64	396.01	267.17
3	3.750	6.76	4.23	4.23	100	34.04	4.23	230.11	143.99
	4.362	7.36	5.41	4.75	100	48.68	5.42	358.28	263.85
						950.30		7603.47	5081.58

nwx^2	$nwxy$	nwy^2
61242.0164	41043.6143	27724.9064
60836.3212	40658.3617	27172.9510
$Sxx=$ 405.6952	$Sxy=$ 385.2526	$Syy=$ 551.9554
		365.8401
		186.1153 $=X^2$

$$b=\frac{385.2526}{405.6952}=0.9496 \qquad (15)$$

$$y=5.3473+0.9496\,(x=8.0011)$$
$$=5.3473+0.9496x-7.5978$$
$$=0.95x-2.25$$
$$m_{10}=\text{Log } 7.6319$$
$$m_{90}=\text{Log } 8.9789$$
$$n=17 \quad \bar{x}=8.0011 \quad \bar{y}=5.3473$$

tract the corresponding correction term. The remainder, or sum of products, obtained by this computation may be termed Sxy. The correction term is calculated by multiplying the total of the nwx column by that of the nwy column and dividing by the total of the nw column.

The sum of squares Sxx is obtained by adding the products of each nwx item (column 9) multiplited by its corresponding x value (column 3) and subtracting the correction term calculated by squaring the total of the nwx column and dividing by the total of the nw column. The sum of squares, Syy, is calculated in a similar manner.

The weighted means for the x and y values are obtained by dividing the sums of the nwx and nwy items (columns 9 and 10, respectively) by the sum of the nw items (column 7). These means are 8.0011 and 5.3473, respectively. To find any point on the probit regression line, multiply the quantity x minus the mean of x by the quotient of Sxy over Sxx and add to the mean of y.

$$5.3473+0.9496(x-8.0011)=0\ 95x-2.25.$$

From this formula may be plotted the probit regression line as illustrated for DDT in figure 1. From it may also be calculated the logarithm of the product of the concentration times the exposure time. For example, the probit for 90 per cent mortality is 6.28, and the logarithm for that mortality due to DDT is calculated as follows:

$$\text{Log 90 per cent}=(6.28+2.25)\,.0.95$$
$$=\text{Log } 8.9789.$$

A dosage of approximately 300 pounds per acre is represented by log 5.000. This subtracted from log 8.9789 gives log 3.9789, which is the logarithm of 9526 minutes (between 6 and 7 days), the approximate exposure time required to give a 90 per cent mortality with that dosage. With 30 pounds per acre of DDT, represented by log 4.000;, the exposure period would be increased to approximately 66 days, or more than 2 months. With an insect whose larval period extends over 2 to 4 years, an exposure period of 2 months is a minor factor, unless an important crop is to be protected within that period.

Normally all the data necessary would be the mortality desired and the exposure period that is practical. With these data known the approximate dosage can be determined and a series of tests can be made under field conditions with dosages in

Table 3.—A summary of the results of experiments with various organic insecticides against wireworms.

Insecticide (1)	Number of Tests[1] (2)	Total Worms (3)	Per Cent Mortality in Check (4)	Regression Formula (5)	Hetero-geneity Factor (6)	Minutes of Exposure Time at 100,000 p.p.b.		Ratio Column 8 to Column 7 (9)
						50 Per Cent Mortality (7)	90 Per Cent Mortality (8)	
DDT	17	2,300	10	$0.95x-2.25$	12.41	428	9,526	22.2
Toxaphene	12	600	20	$1.45x-7.30$	6.86	3,040	23,200	7.6
Chlordane	10	500	22	$2.49x-14.74$	0.32	886	2,989	3.3
Parathion	13	1,300	24	$2.39x-12.10$	14.96	139	490	3.5
Aldrin	17	1,900	10	$0.56x-2.8$	16.41	1.09	210	193.1
Benzene hexachloride (gamma isomer)	11	660	10	$2.03x-6.85$	4.92	6.8	29.4	4.3
Methoxychlor	5	250	18	$1.02x-4.93$	2.38	54,350	780,200	14.4
A bromine analog of DDT	5	250	18	$0.42x-0.04$	6.33	7,424,000	—	—

[1] Only those tests and worms significant to the calculations are listed.

that general range. If it is desired to determine the acucracy of the estimate, or the range of expected results, some method of calculating the fiducial limits may be used. One method is the standard error with or without correction by the heterogeneity factor. The use of the standard error alone would change the exposure period for 300 pounds per acre of DDT and a desired mortality of 90 per cent from 6.6 days to a range of 5.7 to 7.7 days, while for the same mortality and a 30-pound dosage the 66-day exposure is changed to a range of 57 to 77 days. With the additional correction of the heterogeneity factor, the first range becomes 4 to 11 days and the latter 31 to 112 days.

This heterogeneity factor is a measure of the approach of the various tests to a uniform pattern. To obtain this factor, divide the square of Sxy by Sxx and subtract the quotient from Syy; then divide the remainder by two less than the number of tests in the experiment.

$$[Syy-(Sxy)^2/Sxx]/(N-2);\text{ or}$$
$$[551.9554-(385.2526)^2/405.6952]/(17-2)$$
$$=12.4077.$$

To make the correction, multiply the variance by the factor and extract the square root to obtain the standard error. The same results would be obtained by multiplying the standard error by the square root of the factor. With this material the heterogeneity factor is larger than with many of the materials tested. The results of the tests with this type of DDT are not grouped very closely along a straight line; yet there is no indication of curvature. In other experiments the use of different brands or types of the same insecticide, also the combining of two or more experiments conducted at different times, has increased the irregularity of the results. Each test should be as complete as possible, with as many wireworms as is practical, and with all the factors controlled—wireworms, soil moisture, temperature, methods, Even at best there is variation, apparently in part due to inherent characteristics of some of the insecticides.

Discussion.—For the purposes of these laboratory experiments the method appears to give worthwhile results. A large number of field records, obtained by sifting and by baiting in treated areas, have been checked against the simple probit regression lines without any correction. With the dosage known and the mortality indicated, the exposure time fits theknown lapse of time with much greater accuracy than was to be expected. At most, all that is expected of a laboratory test is an indication of the range within which the field tests are to be made. It is important in field tests, however, to know whether the dosages should be 1, 2, 4, and 8 pounds or 9, 18, 36, and 72 pounds per acre; in other words, whether the tests should be arranged on a basis of 3 pounds or 27 pounds per acre. With the values that are used in this paper, these dosages would be represented by the logarithms 3.0000 and 3.9542, respectively, and should be readily distinguishable.

The comparison of the chemicals as regards the reaction of wireworms is illustrated by the position and slope of the probit regression line in figure 2. Those materials that require the smaller amounts and the shorter exposures are naturally toward the left side of the chart. Those that kill 90 per cent of the worms with but little more concentration or exposure time than required for 50 per cent, or even 10 per cent, approach the perpendicular.

On the other hand, a material that kills a few individuals at low concentration and exposure, but is slow in increasing its kill, may drag across the chart on a line approaching the horizontal. Aldrin is

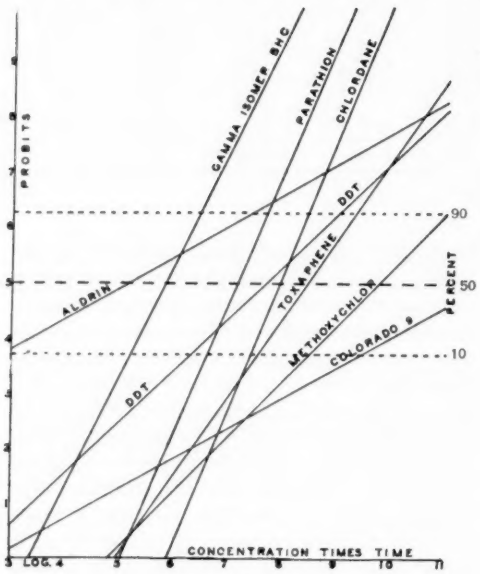

FIG. 2.—Probit regression lines for various insecticide to illustrate relative mortality of wireworms.

an example. With a dosage of 1/3 pound per acre, the exposure time required for 10, 50, and 90 per cent mortalities would be approximately 6 minutes, 18 hours, and 146 days, respectively, whereas chlordane at 100 times this dosage will show the same mortalities with exposure times of approximately 2, 6, and 19 days. With aldrin it takes 190 times as long or as much to kill 50 per cent as it did 10 per cent, or to kill 90 per cent as it did 50 per cent. Chlordane with its more perpendicular line takes only 3 times as long to kill 50 per cent as it did 10 per cent, or to kill 90 per cent as it did 50 per cent. DDT with its intermediate slope takes approximately 22 times as long to kill 90 per cent as 50 per cent. Table 3 gives a summary of the various chemicals tested. Each record is based on a single experiment to eliminate variation. Many other experiments have been made and analyzed, with very comparable results.

The method suggested requires the use of several tables. The logarithms were taken from a four-place table, such as is found in many handbooks. The probit, weighting, and working probit tables used were all simplified forms in Finney (1947) The first two are in Bliss (1935) and all three are to be found in Fisher & Yates (1943).

SUMMARY.—The comparison of the toxicity of two insecticides to wireworms necessitates the determination of mortalities in relation to time and concentration. The common practice of making a single comparison at some specific mortality level is of little value, owing to the inherent differences in the various insecticides. A modified form of probit analysis, in which the probit of mortality is calculated against the logarithm of the product of exposure time multiplied by concentration, is made to produce a single straight line. This line provides both a visual measure of the efficiency of the insecticide against wireworms, *Limonius* spp., for comparison with others and a ready and accurate estimate of the dosage to be tested in the field. The accuracy of the experiment and the range of the estimates may be determined. Most laboratory tests, however, are intended to give rough approximations, and the eye-fitted regression line may prove to be sufficient without further calculations.

LITERATURE CITED

Bliss, C. I. 1934. The method of probits. Science **79**: 38–9, 409–10.
Bliss, C. I. 1935. The calculation of the dosage-mortality curve. Ann. Appl. Biol. **22**: 134–67.
Bliss, C. I. 1937. The calculation of the time-mortality curve. Ann. Appl. Biol. **24**: 815–52.
Bliss, C. I., 1940. The relation between exposure time, concentration, and toxicity in experiments on insecticides. Ann. Ent. Soc. Amer. **33**(4): 721–66.
Finney, F. D. 1947. Probit analysis. Cambridge University Press.
Fisher, R. A. and Yates, F. 1943. Statistical tables for biological, agricultural and medical research (2nd ed.). London.
Wadley, F. M. 1945. The evidence required to show synergistic action of insecticides and a short cut in analysis. U. S. Bur. Ent. and Plant Quar. **ET-223.**

Further Studies of the Control of Insects of Red Clover in New York

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In the study of the control of insects of forage crops by insecticides, as in the study of the control of any insect, one must consider costs, available and proper equipment for the application of the insecticides, formulation of the toxicants, poisonous residues to bees and other beneficial insects as well as to warm-blooded animals, the effects of the toxicants on the palatibility of the forage, the long time effects of the insecticides in a rotation with other crops, and last but not least, in the deposition of toxic residues in the body fat of dairy cows and the secretion of these materials in the butterfat of milk.

While all the factors mentioned are of utmost importance in evaluating any insecticides for use on forage crops, the limiting factor in the use of certain insecticides on hay, pasture, and silage is the appearance of toxic residues in meat, milk, and milk products. While methods of eliminating contaminants from meat and milk products must be studied and are of primary interest, such basic considerations as "what will kill the bugs" are still important, especially on insects of forage crops where little information is available not only on the toxicity of insecticides but also on the insects themselves. Therefore, in conjunction with examinations of insecticide residues on forage crops and the the effects of these residues in the diet of dairy cattle, extensive investigations on the toxicity of several organic insecticides to insects and other arthropods of forage crops were initiated in the field in 1947.

Preliminary observations of the control of 13 species of insects of medium red clover and northern variegated alfalfa using 9 different insecticides as dusts were conducted in Oswego and Cayuga counties in New York during 1948. These results were reported in an earlier paper (Gyrisco & Marshall 1950). Further studies of the control of the insects of medium red clover by the use of 7 different chlorinated hydrocarbon and organophosphorous insecticides were continued at Fulton in Oswego county during 1949.

While 27 species of insects of medium red clover were investigated during the work in 1947 and 1948, only 15 species of clover insects occurred in large enough numbers to be considered in this paper. These were the red-legged grasshopper, *Melanoplus femur-rubrum;* the meadow spittlebug and its variations, *Philaneus leucopthalmus;* the lined spittlebug, *Phillaneus lineatus;* the potato leafhopper, *Empoasca fabae;* the clover leafhopper, *Aceratagallia sanguinolenta;* the six-spotted leafhopper, *Macrosteles divisus;* the tarnished plant bug, *Lygus oblineatus;* the lesser clover leaf weevil, *Hypera nigrirostris; Sitona flavescens*; *Hypera meles;* and *Tychius* spp. No attempt was made, in the examinations of the net sweepings in the various experiments, to separate the various species of grasshoppers and spittlebugs. Therefore, all the different individuals of these species of insects are listed in the several tables under the headings of "grasshoppers" and "spittlebugs."

In early July, three experiments were laid out in a large, uniform, field of first cutting-year, pure, medium red clover. In the first field test (Table 1), the plots, which were 18 ft. wide and 150 ft. long, were replicated three times and randomize within blocks. Ten-foot truck lanes and guard rows surrounded each plot. In the second and third experiments, the treatments were set up in a tandem series of unreplicated, wide blocks, each 75 by 36 feet in size.

All dust applications in all of the experiments were made with a single outlet even-feed power duster[3] equipped with an aluminum alloy tubular boom which was suspended by wire cables 2 feet from the ground and to the right of the truck. The dust applications were made at a truck speed of approximately 2 mph. All of the dusts which were proprietary formulations were weighed on a platform scale before application, and the residues remaining in the hopper were weighed after application in order to determine the exact amount of

[1] Associate professor and graduate assistant, respectively.

[2] The authors acknowledge the assistance of A. A. Muka in this work.

[3] Niagara Model AA "Even-feed" Alfalfa Duster powered with a Model ZZ Briggs and Stratton Engine.

each toxicant applied per acre. Although an attempt was made to apply 1 pound of actual toxicant per acre in each case in all the experiments, the amounts applied per acre (see tables) varied from 0.75 to 1.35 pounds per acre for all the insecticides except benzene hexachloride which was a heavy, sticky material with very poor flowability. Only about 0.5 pound of actual toxicant (gamma isomer) of benzene hexachloride could be applied without retreating the plots or altering the equipment. The variation in the deposits of the toxicants points out the difficulties involved in obtaining similar deposits between replications and tests in field experiments. It emphasises the need for machinery that will give a continuous uniform output, for the use of materials that have similar physical characteristics, and for an accurate measurement and control of the speed of the applicator.

Table 1.—Summary of insect counts from 60 net sweeps per treatment showing the control of insects of medium red clover with four organic insecticides applied as dusts July 11, 1949. Fulton, N. Y.

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds					
	Dieldrin 0.85	Parathion 0.85	Chlordane 0.85	BHC 0.40r	Toxaphene 0.90	Check
	48 hour count					
Grasshoppers	1	1	0	4	1	5
Spittlebugs	0	4	2	2	1	6
Potato leafhopper	0	0	0	0	0	0
Clover leafhopper	0	0	2	0	2	0
Six-spotted leafhopper	0	1	1	1	0	0
Tarnished plant bug	0	0	0	2	0	5
Sitona flavescens	1	0	3	10	7	9
Lesser clover leaf weevil	0	0	0	0	1	1
Hypera meles	1	0	0	0	3	1
Tychius spp.	0	0	2	2	0	2
Totals	3	6	10	21	15	29
Insect Complex Per cent Control	90	79	66	28	48	—
	72 hour count					
Grasshoppers	2	2	2	3	9	15
Spittlebugs	1	1	1	2	3	10
Potato leafhopper	0	0	1	0	0	1
Clover leafhopper	2	0	3	0	5	16
Six-spotted leafhopper	1	0	3	1	3	3
Tarnished plant bug	0	4	0	2	0	11
Sitona flavescens	0	0	5	4	9	20
Lesser clover leaf weevil	0	0	1	0	1	0
Hypera meles	0	0	0	0	0	0
Tychius spp.	0	0	6	5	9	23
Totals	4	7	22	17	39	99
Insect Complex Per cent Control	96	93	78	83	61	—
	1 week count					
Grasshoppers	3	5	2	6	6	38
Spittlebugs	2	2	0	3	0	10
Potato leafhopper	0	3	0	1	1	2
Clover leafhopper	1	0	0	2	3	0
Six-spotted leafhopper	0	2	1	0	0	1
Tarnished plant bug	3	0	0	0	2	13
Sitona flavescens	1	1	4	8	8	40
Lesser clover leaf weevil	0	0	1	0	1	1
Hyper meles	0	0	1	0	0	0
Tychius spp.	0	0	10	37	15	22
Totals	10	13	19	57	36	127

Table 1.—(*Continued*)

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds					
	Dieldrin 0.85	Parathion 0.85	Chlordane 0.85	BHC 0.40r	Toxaphene 0.90	Check
Insect Complex Per cent Control	92	90	85	55	72	—
		2 week count				
Grasshoppers	26	55	19	44	98	148
Spittlebugs	3	6	3	3	2	8
Potato leafhopper	6	1	2	3	0	4
Clover leafhopper	1	2	6	5	2	4
Six-spotted leafhopper	6	17	8	10	6	13
Tarnished plant bug	7	8	5	1	5	19
Sitona flavescens	0	0	0	0	0	2
Lesser clover leaf weevil	2	3	3	1	6	6
Hypera meles	0	0	0	0	1	0
Tychius spp.	1	3	10	20	27	36
Totals	52	95	56	87	147	240
Insect Complex Per cent Control	78	60	76	64	39	—
		3 week count				
Grasshoppers	29	56	17	18	80	112
Spittlebugs	2	6	2	0	4	1
Potato leafhopper	2	2	1	0	0	0
Clover leafhopper	4	3	1	3	7	0
Six-spotted leafhopper	5	14	4	1	3	12
Tarnished plant bug	10	1	2	2	2	3
Sitona flavescens	2	2	1	2	2	2
Lesser clover leaf weevil	1	5	0	1	3	0
Hypera meles	0	0	1	2	0	3
Tychius spp.	5	6	8	11	4	8
Totals	60	95	37	40	105	151
Insect Complex Per cent Control	60	37	75	73	30	—

From net sweepings, counts of the various insects were made in all of the plots. From these figures estimates were made of the effectiveness of the various insecticides in the several experiments conducted during 1949. Twenty full-arm single sweeps were taken with a short handle (20 inch) standard 15-inch sweep net in a diagonal path across each plot in all of the experiments at varying intervals from 24 hours to 3 weeks. The insects from each plot were placed in a 10-pound paper bag which was fastened at the top by several folds and a paper clip. These bags were placed in a large cyanide barrel in order to kill the insects. After killing, the insects from each bag were separated, identified, and counted. These data are recorded in the various tables.

In the several experiments conducted in 1949, dieldrin, aldrin, heptachlor, and parathion, in that order, were the most efficacious toxicants for controlling the insect complex on medium red clover (Tables 1, 2, 3). Benzene hexachloride, while showing some promise at the concentrations at which it was used, could not be evaluated properly and compared, since it had been used at a lower dosage. Toxaphene, which was highly toxic to certain species of insects, was not as effective in reducing the insect complex as some of the other insecticides tested. Dieldrin and chlordane persisted the longest in their effectiveness on the insect complex while aldrin and parathion, which gave good immediate action, rapidly lost their toxicity one week after application. This loss in toxicity was correlated with a rapid loss in residue, a property which is not unfavorable for an insecticide to be used on forage crops.

If each insect which occurred in numbers

sufficiently large to permit conclusions over the three week period is considered separately, it can be seen that dieldrin, aldrin, heptachlor, chlordane, and benzene hexachloride were all effective for controlling grasshoppers. Dieldrin gave

Table 2.—Summary of insect counts from 20 net sweeps per treatment showing the control of insects of medium red clover with four organic insecticides applied as dusts July 20, 1949. Fulton, N. Y.

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds				
	Dieldrin 0.75	Parathion 0.95	Aldrin 0.80	BHC 0.45r	Check
	24 hour count				
Grasshoppers	0	7	6	12	121
Spittlebugs	1	1	1	0	10
Potato leafhopper	0	0	1	0	0
Clover leafhopper	2	0	2	1	3
Six-spotted leafhopper	0	0	0	0	0
Tarnished plant bug	1	6	0	1	23
Clover head caterpillar	0	1	1	0	2
Clover root curculio	0	0	2	7	6
Sitona flavescens	2	1	10	26	33
Lesser clover leaf weevil	0	0	1	0	0
Hyper meles	0	0	0	0	1
Tychius spp.	0	0	0	1	21
Totals	6	16	24	48	220
Insect Complex Per cent Control	97	93	89	78	—
	48 hour count				
Grasshoppers	1	26	2	11	123
Spittlebugs	2	1	1	0	3
Potato leafhopper	1	0	1	0	2
Clover leafhopper	2	0	1	3	0
Six-spotted leafhopper	2	1	1	0	1
Tarnished plant bug	2	1	4	1	20
Clover head caterpillar	0	1	1	2	0
Clover root curculio	0	0	0	0	2
Sitona flavescens	0	0	0	0	3
Lesser clover leaf weevil	0	0	0	0	0
Hypera meles	0	0	0	0	0
Tychius spp.	0	1	1	0	5
Totals	10	31	12	17	159
Insect Complex Per cent Control	94	81	92	89	—
	72 hour count				
Grasshoppers	1	17	6	6	78
Spittlebugs	0	4	4	0	0
Potato leafhopper	1	0	0	0	0
Clover leafhopper	1	0	0	4	0
Six-spotted leafhopper	0	0	0	0	0
Tarnished plant bug	0	2	7	2	11
Clover head caterpillar	0	0	0	0	0
Clover root curculio	0	0	0	1	0
Sitona flavescens	0	0	1	1	17
Lesser clover leaf weevil	0	1	1	3	5
Hypera meles	0	0	0	0	0
Tychius spp.	0	0	0	2	8
Totals	3	24	19	19	119
Insect Complex Per cent Control	97	80	84	84	—

Table 2.—(*Continued*)

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds				
	Dieldrin 0.75	Parathion 0.95	Aldrin 0.80	BHC 0.45r	Check
	1 week count				
Grasshoppers	0	22	3	7	102
Spittlebugs	0	1	2	0	3
Potato leafhopper	1	1	2	0	0
Clover leafhopper	3	0	1	2	4
Six-spotted leafhopper	0	3	0	1	0
Tarnished plant bug	2	4	4	1	4
Clover head caterpillar	1	0	2	2	0
Clover root curculio	0	0	0	0	0
Sitona flavescens	0	3	3	4	16
Lesser clover weevil	0	0	2	2	1
Hypera meles	0	0	0	0	0
Tychius spp.	0	2	1	1	9
Totals	7	33	20	20	139
Insect Complex Per cent Control	95	76	86	86	—
	2 week count				
Grasshoppers	0	5	4	5	83
Spittlebugs	0	3	0	6	2
Potato leafhopper	4	1	2	3	1
Clover leafhopper	3	1	6	3	2
Six-spotted leafhopper	1	1	1	0	1
Tarnished plant bug	1	3	6	39	4
Clover head caterpillar	3	1	6	3	2
Clover root curculio	0	1	3	0	4
Sitona flavescens	0	0	0	1	2
Lesser clover leaf weevil	0	3	3	1	13
Hypera meles	0	0	1	6	0
Tychius spp.	0	5	1	3	22
Totals	12	24	33	70	136
Insect Complex Per cent Control	91	82	76	49	—
	3 week count				
Grasshoppers	1	8	4	9	20
Spittlebugs	2	3	1	2	1
Potato leafhopper	0	0	1	0	0
Clover leafhopper	15	2	24	16	13
Six-spotted leafhopper	0	0	0	0	0
Tarnished plant bug	0	5	10	11	11
Clover head caterpillar	3	0	0	0	0
Sitona flavescens	0	1	0	0	0
Lesser clover leaf weevil	0	0	0	2	1
Hypera meles	0	0	0	0	0
Tychius spp.	1	2	0	0	1
Totals	19	21	40	40	47
Insect Complex Per cent Control	60	55	15	15	—

excellent immediate and residual kills, controlling 95 per cent of the grasshoppers for 3 weeks or for the duration of the experiment. Aldrin and heptachlor also gave excellent control of grasshoppers, but these toxicants persisted somewhat less than dieldrin in their residual toxicity. Benzene hexachloride killed up to 84 per cent of the grasshoppers 3 weeks after application while chlordane gave good kills of 85 per cent of the hoppers for 2 weeks.

Parathion and dieldrin controlled 98 per cent of *Sitona flavescens* for a period of 1 week and were the most outstanding insecticides tested for that insect.

All of the materials tested showed promise for the control of *Tychius* spp. but dieldrin, parathion, aldrin, and chlordane, in that order, were the best toxicants for controlling these clover seed insects.

The populations of tarnished plant bugs

Table 3.—Summary of insect counts from 20 net sweeps per treatment showing the control of insects of medium red clover with five organic insecticides applied as dusts July 28, 1949. Fulton, New York.

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds					
	Dieldrin 1.35	Parathion 1.15	Aldrin 0.75	BHC 0.50r	Heptachlor 1.00	Check
			48 hour content			
Grasshoppers	0	0	0	4	0	46
Spittlebugs	0	0	1	0	0	2
Potato leafhopper	0	0	1	1	0	4
Clover leafhopper	3	0	0	3	2	0
Six-spotted leafhopper	1	0	0	0	0	0
Tarnished plant bug	0	0	0	0	0	19
Clover head caterpillar	0	0	1	0	1	2
Clover root curculio	0	0	1	2	0	4
Sitona flavescens	0	1	2	3	0	7
Lesser clover leaf weevil	0	0	0	1	0	2
Tychius spp.	0	0	0	0	0	3
Totals	4	1	6	14	3	89
Insect Complex Per cent Control	96	99	93	84	97	—
			72 hour count			
Grasshoppers	0	0	1	3	0	16
Spittlebugs	0	0	0	0	1	2
Potato leafhopper	0	0	1	1	2	3
Clover leafhopper	4	0	0	0	1	8
Six-spotted leafhopper	0	1	2	0	0	1
Tarnished plant bug	0	0	0	0	0	0
Clover head caterpillar	4	0	0	0	1	8
Clover root curculio	0	0	0	2	0	0
Sitona flavescens	0	0	0	1	0	0
Lesser clover leaf weevil	0	0	0	0	0	2
Tychius spp.	0	0	0	0	0	6
Totals	8	1	4	7	5	46
Insect Complex Per cent Control	83	98	91	85	89	—
			1 week count			
Grasshoppers	0	0	0	6	1	18
Spittlebugs	0	0	0	0	0	2
Potato leafhopper	0	1	1	1	0	0
Clover leafhopper	0	1	0	4	1	6
Six-spotted leafhopper	0	0	0	1	1	0
Tarnished plant bug	1	2	0	3	1	6
Clover head caterpillar	2	0	0	0	0	1
Clover root curculio	0	0	0	2	1	1
Sitona flavescens	0	0	0	5	0	5
Lesser clover leaf weevil	0	1	0	4	0	2
Tychius spp.	0	0	0	1	1	2
Totals	3	5	1	27	6	43
Insect Complex Per cent Control	93	88	98	37	86	—

Table 3.—(*Continued*)

Insects	Treatments with Rates of Actual Toxicant per Acre in Pounds					
	Dieldrin 1.35	Parathion 1.15	Aldrin 0.75	BHC 0.50r	Heptachlor 1.00	Check
	2 week count					
Grasshoppers	7	12	9	6	8	29
Spittlebugs	0	0	0	0	2	0
Potato leafhopper	0	0	0	0	1	0
Clover leafhopper	8	2	2	5	12	16
Six-spotted leafhopper	1	0	0	0	0	0
Tarnished plant bug	2	1	4	0	10	10
Clover head caterpillar	0	0	1	0	0	2
Clover root curculio	0	0	0	0	0	1
Sitona flavescens	0	0	0	1	0	2
Lesser clover leaf weevil	1	0	1	1	0	1
Tychius spp.	0	0	0	0	0	3
Totals	19	15	17	13	33	64
Insect Complex Per cent Control	70	77	73	80	48	—

were highly variable and never built up to any serious proportions in the experimental plots. Therefore an accurate evaluation of the effectiveness of the various insecticides was difficult to make. While all of the materials showed some promise for controlling tarnished plant bugs on clover, benzene hexachloride, dieldrin, parathion, toxaphene, and chlordane appeared to be the best insecticides tested.

Even though insect collections were made of adult spittlebugs, potato leafhopper, clover leafhopper, clover head caterpillar, clover root curculio, and lesser clover leaf weevil and these counts are recorded in the tables, these insects did not occur in sufficient numbers to permit any conclusions as to the effectiveness of the various insecticides used in these experiments.

While several of these insecticides have given excellent control of the insect complex of medium red clover, these data do not constitute a recommendation for their use. Until further information is available on the fate of these toxicants in beef and dairy cattle, treated hay should not be fed to dairy cattle or beef animals being readied for slaughter.

SUMMARY—Seven different chlorinated hydrocarbon and organophosphorous insecticides were used as dust at the rate of 1 pound of actual toxicant per acre in 3 experiments conducted in Oswego county for the control of the insect complex of medium red clover. Dieldrin, aldrin, heptachlor, and parathion in that order were the most effective materials tested.

LITERATURE CITED

Gyrisco, George G. and D. S. Marshall. 1950. The control of insects of alfalfa and red clover in New York. JOUR. ECON. ENT. 43(4): 438–43.

Control of the Sweetclover Weevil in Indiana[1]

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Studies initiated in 1948 for the control of the sweetclover weevil *Sitona cylindricollis* Fabr. in Indiana have been carried on for three seasons. This pest, which is an especially important problem where sweet clover is being used as a soil improvement crop, is quite general in Indiana. The sweet clover weevil winters as an adult and is one of the earliest of our economic pests to make its appearance in the spring. The adults emerge from hibernation with the first warm days in March. In the early spring they feed on second-year sweet clover until the young plants with the new seedings have germinated. Then they move to the new seedings and strip the young plants, leaving nothing but crescent-cut leaves so typical of their feeding. This feeding is usually too severe for the young clover and the stand is greatly reduced and often entirely killed. The adults mate and then lay their eggs beneath the surface of the soil, egg laying continuing into June, but decreasing rapidly with the insurgence of hot, arid weather. The young larvae, on hatching, feed on the rootlets of the clover but by this time surviving plants are quite sizeable and able to sustain this injury. Even though the adults emerge in large numbers during August, sweetclover plants are so large by then that the weevils rarely do severe damage.

Since it is necessary to protect new seedings of sweetclover early in the spring, control is aimed at the adults at this time. Studies have been made using chemical treatments as follows:

1. Insecticide dusts applied with a hand duster.
2. Insecticide dusts applied by airplane.
3. Insecticide sprays applied with low-volume ground equipment.
4. Insecticide dusts using pyrophyllite as a carrier applied as a top dressing with a fertilizer spreader.
5. Insecticides compounded with fertilizers and applied as a top dressing with a fertilizer spreader.

Methods of Taking Data.—The sweet clover weevil migrates about the field to a great extent and consequently it is hard to take accurate data as to the actual mortality of weevils due to the various treatments. Counts have been made by sweeping. Twenty-four hours after treatment differentials can be found between various treatments using this method, but within a week populations may have migrated so much that differences cannot be observed.

Counts of the number of dead weevils per square foot on the surface of the ground have been made with highly significant results, but the problem of scavengers is encountered. Also some materials kill more slowly than others and the weevils have time to crawl into crevices to die where they are not noticed.

Most reliable data are obtained from actual stand counts; that is the number of plants surviving per square foot. Feeding counts based on the number of notches per leaflet show highly significant differences between treatments. Rating systems of from 1 to 6 and 1 to 9 have been used with success; the low figure being good while a high figure is poor. This system is used also for rating size and vigor of stands.

Toxicity Tests from Ground Dusting.—Early in 1948 toxicity tests were run by treating small plots with a hand rotary duster. Individual plots measured 10 by 10 feet and each treatment was replicated five times. This study was conducted as an exploratory test on second-year sweet clover before the new clover seedings came on. Because of the migratory habits of the weevil, these plots were too small for a seasonal study. However, they were adequate to show toxicity differences of the different materials 48 hours after treatment. Square-foot surface counts of dead weevils in each plot were taken. Data are summarized in table 1.

Statistical analysis indicated highly significant differences. The average mortality column in table 1 shows that control with toxaphene and parathion was significantly higher than in DDT, methoxychlor, chlordane and the untreated plots. Benzene hexachloride gave control exceeding that of these same materials to a degree which approached high significance. Differences between DDT, methoxychlor,

[1] Journal Paper No. 493.

chlordane, and the untreated checks were not significant. Differences between the two rates of parathion were not significant but there was a nearly significant difference in control with 1 pound of parathion per acre over 2.5 pounds of toxaphene.

Possibly DDT killed more slowly and gave the weevils time to move into crevices to die unnoticed. Subsequent experiments all show DDT to be highly effective against the weevil with a long residual effect but not so spectacular the first week as parathion which has little residual effect.

AIRPLANE DUSTING.—Thirty-five acres of sweet clover planted in oats were dusted by airplane on May 25, 1948 to control the weevil. One half of the field was dusted with 5 per cent DDT applied at the rate of 40 pounds per acre and the other half was treated with 5 per cent toxaphene at the same rate. Before treatment there was 100 per cent feeding on all plants and many had been destroyed completely. A field of sweet clover in oats on an adjoining farm showed about the same amount of injury and was used as an untreated check. Although more dead weevils were found on the toxaphene-treated area there was no apparent difference between the toxaphene and DDT treated parts of the field. Both materials seemed to give adequate control as the sweet clover overcame its set-back and the plants that had not been killed before treatment produced a fair stand in most of the field. Airplane treatment will usually save a stand from depletion, but is not so effective as ground treatment. Airplane treatments are recommended later in the season when the nurse crop is too high for ground equipment, or when, due to wet weather, it is impossible to use ground equipment.

Table 1.—Sweetclover weevil mortality 48 hours after treatment with insecticidal dusts.

TREATMENT	POUNDS TOXICANT PER ACRE	AVERAGE NUMBER OF DEAD WEEVILS PER SQUARE FOOT
None	0	0
DDT	2.5	1.4
Methoxychlor	2.5	1.2
Chlordane	2.5	1.8
Toxaphene	2.5	4.8
Benzene hexachloride	0.5	2.6
Parathion	0.5	5.2
Parathion	1.0	6.8
Least significant difference	19:1	2.1
	99:1	2.8

GROUND SPRAYING.—Experiments were conducted on second-year sweet clover to determine the value of liquid sprays in weevil control. Second-year sweet clover was used because the plants are larger and differential leaf feeding data can be obtained more readily.

A latin-square experimental design was used with six treatments. Each plot measured 30 by 30 feet. Materials were applied with a small experimental sprayer mounted on bicycle wheels and equipped with a 10 foot boom for legume spraying. Sprays were applied at 40 pounds pressure using CO_2 as a propellent. A speedometer is attached to the sprayer so that accurate dosages can be applied to treated plots.

Data were taken 24 hours after treatment by sweeping for live weevils. Signifi-

Table 2.—Effect of liquid insecticide treatments on the sweetclover weevil.

TREATMENT	AMOUNT PER ACRE		AVERAGE NO. WEEVILS PER 20 SWEEPS 24 HOURS AFTER TREATMENT	AVERAGE NO. NOTCHES PER 100 LEAFLETS 2 WEEKS AFTER TREATMENT
	Gallons Spray	Pounds Toxicant		
None	0	0	5	260
DDT (25% Emulsion)	7	1.5	2	88
Toxaphene (60% Emulsion)	7	1.5	2.3	125
Lindane (25% Emulsion)	7	0.25	5	172
Parathion (25% Wettable)	24.5	1.0	1	108
EPN[1] (27% Wettable)	27	1.0	3	136
Least significant difference		19:1	2.0	68
		99:1	2.8	93

[1] Ethyl-p-nitrophenyl thionobenzene phosphate.

cant differences in weevil populations are evident in table 2. However, differences could not be obtained a week later using this method of sampling.

Two weeks after treatment stems were picked in each plot and the number of notches caused by weevil feeding were counted for each leaflet. From these counts the total average number of weevil notches per 100 leaflets was calculated. This method seems to give the most reliable data. Data are summarized in table 2.

The weevil mortality column in table 2 shows control with parathion, DDT, and toxaphene to be highly significant. Ethyl-p-nitrophenyl thionobenzenephosphate was just under significance and lindane was apparently ineffective. The differences between parathion, DDT, and toxaphene were not significant.

Data compiled from leaflet injury showed significant differences between all materials used and the untreated check. All materials except lindane showed highly significant differences. Although DDT was apparently better than other materials the differences were not significant except when compared with lindane.

TOP DRESSING THE SOIL WITH INSECTICIDES.—Since the sweet clover weevil habitually crawls along the ground, it seems logical that it might be controlled best by applying to the surface of the ground an insecticide which the insect might contact. Such experiments were carried out both in 1949 and in 1950. Materials were applied in the spring when the young clover first germinated. This was before the two-leaf stage, which is generally the recommended time for spraying. The dilute insecticides were applied to the ground with a fertilizer spreader. In 1949 an inert carrier was used, but in 1950 superphosphate and rock phosphate were used as carriers since it seemed more feasible economically to try to combine an insecticide with a fertilizer and thus take care of two problems in one operation.

In 1949 sweet clover sown with oats was treated. An 8 by 8 latin-square experimental design was used. Plots were 20 by 20 feet. After oats harvest the clover stands were rated, using a rating system of 1 to 6; 1 being excellent; 3–4, average; and 6 poor. Data are listed in table 3.

Statistical analysis showed significant differences among the treatments. Best stands were obtained with DDT or dieldrin. Both of these materials have long residual effects and were significantly better than the untreated checks.

Since no material has appeared appreciably better than DDT for the control of the sweet clover weevil, more comprehensive studies were made in 1950 using different concentrations of DDT with both superphosphate and rock phosphate as carriers for the toxicant. Both superphosphate and rock phosphate checks were used without the toxicant. The phosphate carriers were used at the rate of about 400 pounds per acre. Treatments were applied to germinating sweet clover which had been sown in oats at the rate of eight pounds to the acre. Plots were enlarged to 40 by 40 feet. Six treatments were replicated six times.

Data summarized in table 4 were taken as follows three weeks after treatment. Actual stand counts were made at random by taking square-foot samples from each

Table 3.—Sweetclover stands in treated plots after oats harvest, 1949.

TREATMENT	LBS. TOXICANT PER ACRE	AVERAGE RATING[1]
None	0	4.1
DDT	2.5	3.0
Methoxychlor	5.5	3.5
Toxaphene	3.0	3.9
Benzene hexachloride (0.5% gamma)	0.75	3.4
Parathion	1.2	4.0
Aldrin	1.5	3.8
Dieldrin	.5	3.1
Least significant difference	19:1	1.0
	99:1	1.4

[1] Ratings made four months after treatment using scale of 1–6; 1 being excellent; 3–4, average; 6, poor.

Table 4.—Experiment with DDT in combination with rock phosphate and superphosphate to control sweetclover weevil.

FERTILIZER	LBS. DDT PER ACRE	PLANTS PER SQ. FOOT	VIGOR RATING[1]	WEEVIL-INJURY RATING[1]
Rock phosphate	0.5	26.9	7.27	7.55
Rock phosphate	1.5	34.9	4.21	4.60
Superphosphate	0.5	32.3	4.83	6.55
Superphosphate	1.5	46.3	3.61	3.55
Rock phosphate	0	21.1	7.10	7.21
Superphosphate	0	28.8	5.05	6.38
Least significant difference				
	19:1	12.4	2.55	1.9
	99:1	16.8	3.45	2.6

[1] Ratings made using a scale of 1–9; 1, being excellent; 5, average; 9, poor.

Table 5.—Effect of DDT on stand, vigor and weevil injury.

POUNDS OF DDT PER ACRE	PLANTS PER SQUARE FOOT	VIGOR RATING[1]	WEEVIL INJURY RATING[1]
0	25.0	6.1	6.8
0.5	29.6	6.1	7.1
1.5	40.6	3.9	4.1
Least significant difference			
19:1	8.8	1.8	1.4
99:1	11.9	2.4	1.9

[1] Ratings made using a scale of 1–9; 1, being excellent, 5, average; 9, poor.

Table 6.—Comparison of phosphate type on stand, vigor and weevil injury.

FORM OF PHOSPHATE	PLANTS PER SQUARE FOOT	VIGOR RATING[1]	WEEVIL INJURY RATING[1]
Rock phosphate	27.7	6.2	6.5
Superphosphate	35.8	4.5	5.5
Least significant difference			
19:1	7.2	1.5	1.1
99:1	9.7	2.0	1.5

[1] Ratings made using a scale of 1–9; 1, being excellent; 5, average; 9, poor.

plot and counting the number of plants surviving. From these counts the number of plants per square foot were calculated. Using a rating system of 1 to 9; with 1 being excellent; 5 average; and 9 poor, the plots were also rated on vigor and visible feeding injury. The author was assisted by two agronomists, R. L. Davis and W. B. Wilder, in making these ratings. The ratings in table 4 are an average of those given by the three investigators.

Examination of table 4 shows several trends to be evident.

1. All treatments with superphosphate show greater vigor, more plants per square foot, and less visible weevil injury than corresponding treatments with rock phosphate. The P_2O_5 in superphosphate is readily available to growing plants and may be used to stimulate the growth of sweet clover seedlings so needed to overcome much of the weevil injury. The superphosphate plots show less injury because the plants are larger and the injury is spread over more surface area.

2. The addition of DDT to superphosphate is needed. All treatments follow a pattern indicating differences where each concentration of DDT in superphosphate is better than the same in rock phosphate, even though the differences are not all significant.

Further analysis of the data in table 4 showed that there was no interaction between either superphosphate and DDT or rock phosphate and DDT. Being a factorial experiment with two factors; type of phosphate and concentration of DDT, separate analyses for both were made. The effect of DDT at different concentrations is presented in table 5. Table 4 compares rock phosphate with superphosphate.

These data show that when a per acre dosage of one and a half pounds of DDT was applied there was a decrease in weevil injury of high significance and a highly significant increase in the number of plants per square foot. An increase in the vigor of the plants just under high significance was also obtained. A half pound dosage of DDT per acre was ineffective.

Comparison of rock phosphate with superphosphate shows that there was a significant increase in the number of plants per square foot with superphosphate over rock phosphate. Superphosphate also increased the vigor of the clover to a point just under high significance over rock phosphate. Since neither superphosphate nor rock phosphate is a toxicant, differences in weevil injury would not be expected, but the more vigorous plants produced by the action of superphosphate could make the injury less apparent. This is evidenced on superphosphate treatments by a decrease in weevil injury that is just under significance.

COMPARISON OF DDT-SUPERPHOSPHATE TOP-DRESSED CLOVER WITH DDT-SPRAYED CLOVER.—Part of the experimental field on which the DDT-superphosphate experiments were placed was also sprayed with two pounds of DDT to 15 gallons of water per acre. This treatment was applied when the clover was in the two-leaf stage. Good control was obtained, but many of the earlier germinating plants were lost and the stand was thinner and less vigorous than the stand top-dressed with DDT and superphosphate.

SUMMARY.—Experiments have been carried on for three seasons to find a method of control for the sweet clover weevil. Studies have been made in the use of insecticidal dusts and sprays applied both with ground and air equipment. The most recent studies have been based on the application of insecticides mixed with an inert material or with phosphates and applied as a top dressing with

a fertilizer spreader. The phosphate-insecticide treatment appears most promising. The best stands of sweet clover were obtained in 1950 where a per acre dosage of one and a half pounds of DDT with 400 pounds of superphospnate was applied as the clover was germinating. The DDT dust on the ground is contacted by the weevils as they crawl from their hiding places to the plants. The superphosphate on the other hand gives the plants a quick boost so that they are able to grow faster and thus overcome much of the weevil injury.

European Corn Borer Damage to Grain Sorghums[1]

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The European corn borer, *Pyrausta nubilalis* (Hbn.), has been reported to attack sorghums on several occasions (Baker & Bradley, 1948; Babcock &Vance, 1929; Clark, 1934; Dicke, 1932; Hodgson, 1928; Huber *et al.*, 1928). The corn borer was probably introduced into North America from Hungary or Italy in broomcorn, a type of sorghum (Baker & Bradley 1948). Hsu (1936) reported that some varieties of sorghum in China were resistant to stem borers, including the European corn borer and several other species. Hodgson (1928) reported that several types of sorghums were rather heavily infested by the multiple-generation strain of the corn borer in Massachusetts, with kafir showing the least infestation. Huber *et al.* (1928) stated that infestation of sorghums was relatively light in Ohio where the European corn borer was predominantly the single-generation strain. Beck & Lilly (1949), working in the laboratory with larvae derived from the single-generation population of European corn borer, reported sorghums to be resistant. Newly hatched corn borer larvae reared on Amber cane and South Dakota selection 20-30-S showed larval mortality ranging from 0 to about 80 per cent, which Beck & Lilly correlated with the cyanide content of the leaves of the sorghum plant.

The European corn borer spread into the eastern edge of the sorghum growing area of the United States in 1949 and 1950. Infestations were found in fields of sorghum during both years. The principal observations reported here were made in the sorghum variety nursery at Manhattan, Kansas, on the Agronomy Farm in 1950. An infestation of five stalks out of a total of 79 examined was recorded in one row. The damage was evident about the middle of September when the heads of borer-infested stalks began breaking over. The second generation of borers caused the damage. The sorghum had been planted on June 5 to 7, 1950, and the plants were probably too small to be attractive to the few ovipositing females of the first generation then present in the area. European corn borer moths began to emerge during the last week in May, 1950.

In certain respects the feeding and damage on sorghum were similar to those on corn. Some tunnels were found in midribs of the leaves and in the leaf sheaths. Holes and skeletonized areas seen in the leaves of infested plants may have been made by the young larvae. Holes into the stalk were found from near the ground level to the center of the head, but most of the holes and tunnels were in the upper third of the plant. Breakage of the stalk was most common just above the flag leaf and in or just below the head, but occurred anywhere along the stalk.

The infestation of sorghums differed from that in corn in several respects. The burrows occupied relatively more of the diameter of the stalk in sorghum than in corn because of the more slender stalk of the former. They also appeared to be shorter than those made by borers of the same size in corn. Also, the tunnels were often partly filled with liquid from the plant. Perhaps a third of the larvae seen in mid-September were in webs among the young kernels in the heads. The webs

[1] Contribution 585, Department of Entomology and 440, Department of Agronomy.

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joined spikelets with larval excreta and furnished protection for the larvae while feeding. In a few cases tunnels were not found in stalks where larvae were infesting the head in this manner. In other cases the larvae apparently occupied a tunnel in the main stalk of the head part of the time, the webs being connected with this tunnel. The stalks of sorghum containing European corn borer larvae were much more heavily lignified than were stalks of borer-infested corn, when dissected in December.

FIG. 1.—Double Dwarf White Sooner Milo damaged by European Corn Borer. Heads hanging down like this are missed by the combine in harvesting. Borer holes were found from the ground level up to the middle of the head, but mostly in the upper third of the plant.

It would be of interest to know how severe the infestation by the European corn borer might be in sorghums grown on a field scale in Kansas. A somewhat similar insect, the southwestern corn borer *Diatraea grandiosella* Dyar, does not attack sorghum except in the near vicinity of corn plants (Wilbur *et al.*, 1950). The 1950 sorghum nursery infested by the European corn borer was far enough from the corn that it would not have been infested by a comparable population level of the southwestern corn borer. Infestations on sorghums by the first generation of either species of borer in Kansas have never been

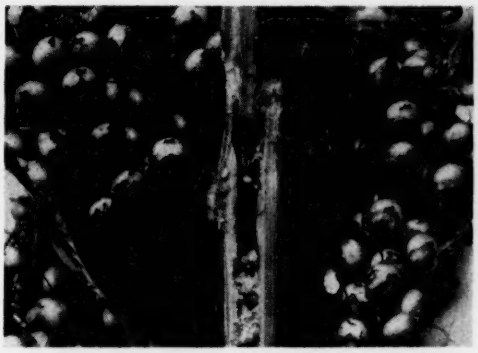

FIG. 2.—Stalk of sorghum cut away to show European corn borer tunneling in the stem or axis of a sorghum head. Many heads were broken over at this point, giving a rather unusual appearance in the field.

seen. This suggests that infestations of sorghum by the European corn borer are more likely to occur where fields of corn and sorghum are present in the same area, and where this insect can build up during the first generation on corn and transfer part of its activities to sorghum for the second generation.

The growth which an insect makes is usually a rough indication of the suitability of its host plant. In one study larvae of the southwestern corn borer which matured on sorghum were about two-thirds as heavy as those that matured on corn (Wilbur *et al.* 1950). That insect appeared to be unable to maintain itself on sorghum in Kansas.

Comparable lots of European corn borer

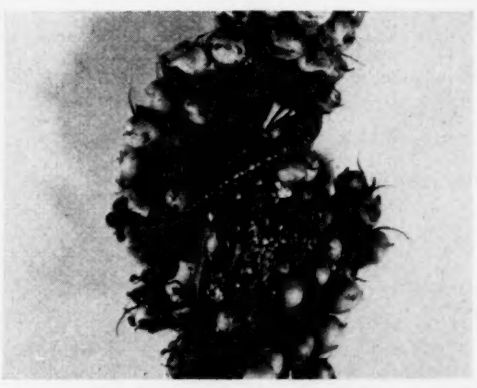

FIG. 3.—European corn borer webbing in a branch of a head of sorghum. The borer apparently feeds on the young kernels. In some cases the web was connected to a burrow in the main stalk of the head. This is a rather unique characteristic of the borer on sorghum.

Table 1.—Weights of hibernating corn borer larvae taken from corn and from sorghum in Kansas.

	European Corn Borer Larvae, Agronomy Farm, Manhattan, Kansas, 1950				Southwestern Corn Borer Larvae (after Wilbur *et al.*, 1950)	
	Pride of Saline Corn	Misc. Grain Sorghum Varieties	Corn Inbred Hy	Sorghum Club× Westland 46W58	Corn Kiowa County 1943	Sorghum Kiowa County 1943
Number of larvae	35	31	25	22	27	27
Average weight of larvae in mg.	99	108	105	106	260[1]	176[1]
Range in weights of larvae in mg.	53 to 153	74 to 158	69 to 151	80 to 156	82 to 420	82 to 283

[1] t=3.82 highly significant.

larvae from corn and sorghum were collected near Manhattan, Kansas, in November, 1950, and weighed. The results are recorded in table 1 together with similar data for the southwestern corn borer. In contrast to the southwestern corn borer, the European corn borer appears to thrive as well on some sorghums as on corn, or even better, at least after larvae once become established. No information is available on comparative establishment of the first instar larvae on these two crops in Kansas.

The infestation in the sorghum nursery was too light to be of much significance for a study of varietal resistance. In 1950, the infestation was confined mostly to varieties of a combine type which had milo in their parentage. The more heavily infested strains also were earlier in heading than many, but not all, of the uninfested strains. Infestation was difficult to find in stalks of the taller and later varieties, many of which were forage sorghums. In 1949, however, infestations were reported by Kansas entomologists in fields of forage sorghums in two locations.

Literature Cited

Babcock, K. W. and A. M. Vance. 1929. The European corn borer in Central Europe. U.S.D.A. Tech. Bul. **135.**

Baker, W. A. and W. S. Bradley. 1948. The European corn borer: Its present status and methods of control. U.S.D.A. Farmers' Bul. **1548.**

Beck, D. D. and J. H. Lilly. 1949. Progress report on European corn borer resistance investigations. Iowa State College Jour. Sci. **23:** 249–59.

Clark, C. A. 1934. The European corn borer and its controlling factors in the Orient. U.S.D.A. Tech. Bul. **455.**

Dicke, F. F. 1932. Studies on the host plants of the European corn borer, *Pyrausta nubilalis*, Hubner, in southeastern Michigan. Jour. Econ. Ent. **25:** 868–78.

Hodgson, B. E. 1928. The host plants of the European corn borer in New England. U.S.D.A. Tech. Bul. **77.**

Hsu, T. S. 1936. Resistance of sorghum to stem borers. Amer. Soc. Agron. Jour. **28:** 271–8.

Huber, L. L., C. R. Neiswander, and R. M. Salter. 1928. The European corn borer and its environment. Ohio Agr. Expt. Sta. Bul. **429.**

Wilbur, D. A., H. R. Bryson, and R. H. Painter. 1950. Southwestern corn borer in Kansas. Kansas Agr. Expt. Sta. Bul. **339.**

Vanda "Miss Agnes Joaquim" a Host of *Dacus dorsalis*

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Reports of *Dacus dorsalis* Hendel, the oriental fruit fly, infesting flowers of field-grown *Vanda* variety "Miss Agnes Joaquim" were first received in March 1949 from an orchid nursery, in the Nuuanu Valley, Honolulu, Hawaii. On March 21 about 45,000 *Vanda* plants in this nursery were examined, and both buds and flowers revealed a low incidence of infestation. However, what appeared to be perfectly normal *D. dorsalis* eggs, presumably viable were discovered on the lips of open *Vanda* flowers. As a result the shipment of *Vanda* blooms from Hawaii to the mainland was temporarily suspended by administrative action effective March 23, 1949. This development seemed to warrant a series of preliminary experiments to determine whether *Vanda* flowers as shipped to mainland markets constituted a hazard as far as *D. dorsalis* is concerned. Results from these experiments helped to remove quarantine restrictions other than inspection on April 3, 1950.

In an attempt to rear *Dacus dorsalis* from buds or open flowers of *Vanda* orchids, the writer collected 23 field-infested buds from the orchid nursery. These were placed in a petri dish, covered, and held in an incubation cabinet at 25° C. and high humidity. Five larvae were observed in the buds 5 days later. One larva was found to be alive and almost full-grown when the decayed bud wasexamined on April 1. The following day the larvae pupated in the decayed remains of the bud and a male fly was recovered on April 10, 1049. It was evident that extremely suitable conditions had to be provided if *D. dorsalis* flies were to be reared from infested buds.

Since the writer had no information on the indices of infestation in *Vanda* blooms, he made a detailed survey of incidence of infestation in commercial flowers. Blooms (grade A and culls in equal numbers) were delivered to the laboratory 1000 biweekly from Hilo, Hawaii, and a field inspection at the Warne orchid nursery was planned for the intervening weeks.

More than 27,000 blooms were inspected, and infestation was found in only 89 blooms. The largest percentage of recoveries was found to be desiccated eggs, an indication that even though a bloom did become infested in the bud stage, the eggs would immediately become exposed to the sun and drying winds when the bloom opened and desiccation would result.

These preliminary findings, together with further experience with the biology of the oriental fruit fly, made it increasingly apparent that the status of the *Vanda* flower as a host was uncertain and should be subject to more rigid experimentation. Therefore, the writer made three types of experiments, all of which are discussed in this paper.

Artificially Infested Flowers and Buds.—The first type of experiment was made to determine the status of *Vanda* flowers as a host of *Dacus dorsalis* when spikes of commercial flowers and buds were artificially infested with eggs. The experiment was planned to cover a period of 10 weeks. Each week 25 comparable commercially grown spikes of *Vanda* orchids were picked fresh from the nursery, removed to the laboratory, and 1000 *D. dorsalis* eggs attached to the throat of open flowers or beneath the upper petal of advanced buds through the suture, at the rate of 10 eggs to each bud or flower.

The technique followed was rather simple but proved very satisfactory. Two 1-gallon cans were attached to each other by a section of discarded automobile inner tube. The upper can had a hole, 0.5 inch in diameter, pierced through the center. This hole was large enough to receive a florist's orchid tube. The lower can contained sufficient sand to act as ballast and prevent knocking over. Black circles, 6 inches in diameter, were cut from heavy art board, and the centers punctured to receive the spike of an orchid. The black discs provided a suitable background for observing any eggs or larvae that became dislodged or otherwise moved from the spikes during the initial stages of the test. The orchid spike was first inserted through the black disc and into the rubber-capped florist's orchid tube full of water. The whole was then placed in the upper can, the tube being centered and suspended through the hole in the bottom

[1] The author acknowledges the assistance of Walter Carter, under whose direction the present study was made.

of the can. Sand was sifted evenly over the bottom of the lower can, and the spikes were ready for infestation.

Eggs were obtained from caged laboratory-reared flies by providing the flies with tangential orange-skin sections for oviposition. The eggs were removed from the sections with the aid of a fine camel hair brush and transferred to petri dishes containing ink-blackened filter paper moistened with 0.1-per cent cupric chloride solution. The eggs so removed were counted into groups of 10, one group being placed on each bloom with a fine hair brush dipped in clear egg albumen before each infestation. The albumen served as a suitable adhering agent and prevented any dislocation of eggs from the blooms during handling. Upon completion of the infestation the cans containing the spikes were moved outdoors to a fine-mesh, antproof screen cage. The top of the cage was covered with palm fronds to afford shade and protection from the elements. A hygrothermograph was placed in the cage, and a record kept for each weekly run. The spikes were inspected daily, and hatch and larval development closely followed. After exposure in the cage for 1 week, the spikes were removed to tables in the laboratory, and observation was continued there.

The spikes thus treated did not appear to lose any of their good keeping qualities. Flowers were present on the spikes up to 30 days after infestation, thus proving that the flower should still be suitable for larval development, if acceptable as a host.

Egg hatch varied from 24 to 72 hours, depending upon weather conditions. No larval activity was observed beyond the the second dqy after hatch; neither was any activity observed in the tissue, column, or peduncle. This indicated that the flowers are not conducive to normal larval development, and apparently not attractive as a food source to the young larvae.

Each flower provided enough space for the 10 early instar larvae, and also enough vegetative matter for the larvae to feed on if it had been acceptable to them. When 10 larvae were placed upon 1 gram of prepared agar-base media, the larvae survived for 5 days, an indication that larvae could have survived on the *Vanda* bloom and vegetative spike if it had had the necessary host properties required for normal larval development.

ARTIFICIALLY INFESTED VANDA BLOOMS IN INCUBATION CABINETS.—The second type of experiment was conducted to determine whether artificially infested blooms packed in standard commercial shipping boxes (capacity 25 blooms) and sealed with pliofilm covers would successfully carry the immature stages of *Dacus dorsalis* through to final development if placed in near-optimum rearing conditions.

Five standard boxes, each containing 25 blooms infested with 10 eggs each, were placed in a constant-temperature cabinet at 25° C. with relative humidity of about 70 per cent. Because the blooms became moldy after 2 weeks, the wrapper was removed and the blooms were carefully inspected. The saturated condition of the boxes, together with the mold, made it impossible to count the collapsed and hatched eggs; however, from the total of 1250 eggs, only 26 larvae were discovered. These were all dead and none had developed beyond the first instar.

To determine whether the fleshy column of the flower could support larvae should it become infested, 50 *Vanda* blooms were so infested with 10 eggs each. In 25 of the blooms, the eggs were inserted into an incision made on the upper side of the column, well down toward the base. In the remaining 25 blooms an incision was made in relatively the same position on the under surface of the column. The blooms were infested without removal from the spikes, to insure ease of observation and handling. Hatch was observed, but it is significant that the larvae were discovered at the point of incision and not at its base, as expected. In other words, there was no entry into the tissue. The under side of the column was observed with the aid of a mirror. Daily inspections were omitted in favor of thorough examination of the bloom at the end of 7 days when it was hoped any larval activity would be pronounced.

At the close of the 7-day period the blooms were completely bleached, shriveled, and dry (Fig. 1), with no live larvae, and the dead recovered were desiccated and discolored.

INDUCED OVIPOSITION IN VANDA BUDS.—The third type of experiment was made as a result of observations on oviposition in the nursery and field examination of *Vanda* spikes which showed that blooms

were being infested in the bud stage. Here the fly found hosts somewhat resembling its more familiar conditions, a firm survace with slight inclination, a suture to facilitate oviposition, and what appeared to be a moist medium in which to deposit the eggs. However, immediately after the bud opened, these conditions quickly changed. Eggs or larvae were exposed on a veritable film of vegetation, with no protection from the rays of the sun and an insufficiently moist medium to protect them. It was nevertheless deemed desirable to discover what would happen if infested buds were given near-optimum conditions for larval development.

Freshly picked, firm but well-developed buds were inserted by the stem through cheesecloth into water-filled petri dishes, and exposed to gravid *Dacus dorsalis* in rearing cages. Twenty-four buds, 6 to each dish, were exposed to the flies for 48 hours. Flies were observed ovipositing in them frequently during this period, and the petri dishes were removed before the buds began to open. Two of the dishes were immediately placed in a constant-temperature cabinet held at 25° C., and the remaining two were placed in the laboratory at room temperature.

The buds held at room temperature were fully open 3 days after their removal from the cage, thereby facilitating examination to determine the extent of infestation. A total of 44 eggs were found to have been deposited. Of these 20 had hatched, 16 had collapsed, and 8 had failed to hatch. Nineteen larvae were discovered; only 4 were alive, and none survived longer than 24 hours. The blooms held in the constant-temperature cabinet were examined immediately after they had opened sufficiently to allow it. Total infestation was 21 eggs, of which 12 had hatched and 9 had collapsed. Full larval recovery (12) was made, but none survived longer than 36 hours.

The flowers in every case were not considered to be in a condition suitable for larval development due to lack of succulent medium and the absence of decomposition.

A further test was made to discover whether more nearly adequate conditions could be provided for larval development if the buds were exposed to the caged flies, and then placed in sealed containers and held in a constant-temperature cabinet and at room temperature.

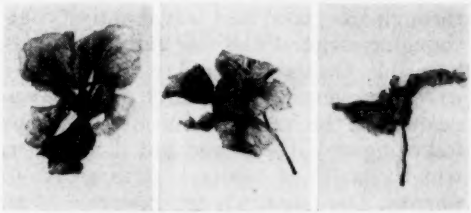

FIG. 1.—Decadence of *Vanda* flowers, showing progression to shriveled, dried condition.

Twenty-four well developed buds were selected and placed six to a petri dish, which was covered with cheesecloth and filled with water. The buds so arranged were exposed to gravid *dorsalis* females for 24 hours. Upon removal from the cages, the petri dishes were packed 2 to a standard *Vanda* shipping box (25-flower capacity), sealed in a pliofilm cover, and placed in an incubation cabinet, temperature 27° C., with a relative humidity of 80 per cent.

Because the boxes were weakened by the high humidity and overflow of water from the petri dishes during transit from the laboratory, they were removed for examination after the test had been in progress 9 days. The buds were in an advanced stage of decomposition. They had not opened, and their shape, character, color, and composition resembled a decadent fruit much more than a flower. Figure 2 shows the stages of decadence of a *Vanda* bud necessary to provide a medium sufficiently succulent and infested with microorganisms to support a larva under near-optimum conditions.

It was immediately evident that the degree of infestation could not be determined in the putrefying media. Examination revealed 14 larvae, 6 of which were dead. The media containing the live larvae were transferred by means of a spatula to a petri dish, and the cover was replaced. Daily observations were made

FIG. 2.—Progressive decadence of *Vanda* buds kept under conditions of high temperature and humidity.

through the glass; and larval activity, although restricted and sluggish, was clearly visible. On the second day only 2 larvae were discovered alive, and 1 of these appeared on the verge of succumbing. The following day there was but 1 survivor, which finally developed sufficiently to pupate. The pupa, when transferred to an isolation jar containing sand, was abnormally small, and finally emerged as an aborted, very much under-sized male.

The recovery of this one adult from an experiment in which over 1,000 *Vanda* buds and flowers were infested with more than 10,000 *D. dorsalis* eggs shows that the *Vanda* flower is not an acceptable host. Eggs and larvae of the oriental fruit fly are naturally protected by the succulent medium present in hosts generally selected, but in the case of *Vanda* this medium does not become favorable unless the bud putrefies.

DISCUSSION.—The correct evaluation of the host relationships of an insect is important at any time, but doubly so when far-reaching quarantine action is involved. When *Vanda* flowers were first reported as a host, quarantine officers had immediately to embargo shipment of these flowers until some treatment could be devised. Actually, however, the data establishing the flower as a host were fragmentary and incomplete, and they were evaluated when very little was known concerning the insect's biology.

We now know that *Dacus dorsalis* will choose almost any suitable niche or surface in which to deposit eggs, even though it belongs to a group which has specific food requirements for normal development. We also know that the wastage resulting from oviposition in unsuitable hosts is enormous. These facts being known, it then became necessary to determine into what host category the *Vanda* flower fell, and whether the fact that the flower is an oviposition point is significant.

From the data obtained from all the experiments, it would appear that the greatest possibility of rearing *Dacus dordalis* from *Vanda* orchids is by the selection of infested buds, placing them in a covered container, and providing what are condidered optimum conditions for larval development. These are a constant temperature of 25° C. and a high humidity (between 70 and 80 per cent), which necessitate the use of an incubation cabine.

The experiments just completed were performed on 1223 *Vanda* blossoms and buds that were infested with 11,815 *D. dorsalis* eggs. Results were negative with the one exception obtained from the petri dish of putrefied *Vanda* buds, from which one deformed *D. dorsalis* male fly was reared.

Most of the dead larvae recovered were located in the throat of the flower, close to the point of infestation. A few individuals were recovered from the lip of the flower, and an occasional one was located in the keel. The flower as a whole represents a very poor host, when we consider that the larvae are naturally at home in hosts with soft pulpy media, sufficiently succulent to allow access for burrowing.

Infestation of *Vanda* blossoms in the field, compiled from examination of 27,335 blooms, amounted to only 89 lndividual flowers, or 0.326 per cent of the total. Whereas, in the inoculation experiment, 1000 individual blooms were positively infested with 10,000 eggs, yet only 1059, or 10.6 per cent, larvae were observed and 284, or 2.8 per cent, of these were alive, none of which survived. To obtain a comparable infestation in field-collected blooms would require 3,071,348 flowers.

Grade A commercial blooms of *Vanda Miss Agnes Joaquim* have been found to be very rarely infested. From 6180 blooms examined, the combined total of blooms with unhatched eggs and larva present was only 0.113 per cent. Culling is meticulously carried out in the packing houses, and because blooms showing the slightest indication of damage, discoloration, or fruit fly punctures are immediately discarded, the possibility of transporting infested blooms elsewhere is very slight. This, together with the conditions necessary to insure the successful rearing of *Dacus dorsalis* on *Vanda Miss Agnes Joaquim*, would appear to substantiate the conclusion that there is no risk of introducing or spreading populations of *D. dorsalis* by means of *Vanda* blossoms. The very fact that even under the most favorable conditions it was impossible to rear *D. dorsalis* through on *Vanda* flowers is the strongest evidence that commercial *Vanda* flowers shipped to mainland markets do not constitute a hazard as far as *D. dorsalis* is concerned.

Dieldrin as a Chemical Control Material on Community Fly Control Programs

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Since 1948 field studies to determine the possible relationship of domestic flies in the transmission of poliomyelitis have been conducted in five metropolitan areas by the Communicable Disease Center in cooperation with local and state health agencies. The cities selected were Phoenix, Arizona; Topeka, Kansas; Charleston, West Virginia; Troy, New York; and Muskegon, Michigan. As an essential part of the studies in each city, full-scale fly control operations were initiated in 1949 to reduce and maintain fly densities at minimum levels. Although principal emphasis was placed upon raising the sanitational levels, the slowness with which such betterment usually proceeds in a community made it necessary to rely chiefly upon chemical control measures during the early phases of the program. These measures, in the main, consisted of periodic space spray applications of 5 per cent DDT in fuel oil, supplemented by residual applications of the same formulation wherever suitable surfaces occurred. As space sprays afford only temporary fly suppression, the frequency of applications required for effective control in areas of high fly densities usually render their continued use more expensive than residual treatments which yield effective abatement for periods of 6 to 8 weeks. In 1949, however, results indicated that the DDT residuals employed did not provide satisfactory control for more than 1 to 3 weeks. Therefore, in the fall of 1949, when laboratory tests and preliminary field applications revealed dieldrin to be effective for extended periods at extremely low dosages[1,2,3] large-scale tests were made with this chemical at the Phoenix, Arizona project. The successful results obtained in this area led to city-wide use in Troy, New York; Charleston, West Virginia; Phoenix, Arizona; and Topeka, Kansas, in 1950.[4] This paper presents a resume of the findings obtained in the 1949 tests and the 1950 operational season.

Methods.—Dieldrin was employed as an emulsion in all treatments. In the 1949 tests at Phoenix, 0.625 and 1.25 per cent rosin-based formulations were used, applications being at the approximate rates of 25 and 50 milligrams per square foot. In 1950 a 0.625 per cent non-rosin emulsion was applied at a rate of 25 milligrams per square foot in all cities except Troy, New York where a 1.25 per cent formulation at 50 milligrams per square foot was used. Stock concentrates consisted of xylene, emulsifier,[5] and dieldrin, and were prepared at a 6.25 per cent strength. One-half of the Charleston area received treatment with a formulation in which rosin replaced the emulsifier.

The insecticide was applied by power or hand spray equipment, the rates of 25 and 50 milligrams per square foot being approximated by spraying surfaces to the point of run-off. For treatment purposes, each city was divided into sections representing the different socioeconomic and sanitational levels. The amount of surface treated varied with the type of section concerned. In substandard residential areas, premises-wide application provided coverage of all fly resting surfaces, including front and back porches and the exterior wall surfaces of dwellings up to 8 to 10 feet, privies, fences, bushes and lower branches of trees, and the exterior and interior surfaces of animal shelters. With the latter, particular care was exercised to prevent contamination of animal feed, water, or ground litter.

In the business and better class residential areas, treatment was focused upon garbage stations, where application consisted of spraying the inside and outside of garbage cans plus 50 square feet of adjacent wall surface and 25 to 30 square feet of ground area. Animal shelters also were treated.

[1] Baker, Walter C. and Paul P. Maier. (Unpublished manuscript) Municipal Fly Control with Dieldrin Spray Residues. Communicable Disease Center, Savannah, Ga.

[2] Quarterman, Kenneth D. (Unpublished manuscript) Field Studies on the Control of DDT-Resistant Flies. Communicable Disease Center, Savannah, Ga.

[3] Quarterman, Kenneth D. and Jens A. Jensen. (Unpublished manuscript) The Outdoor Residual Effectiveness of Several Chlorinated Hydrocarbons. Communicable Disease Center, Savannah, Ga.

[4] The authors gratefully acknowledge the assistance given by the Staff of the Savannah Laboratory of the Communicable Disease Center in planning and conducting these tests. Appreciation is also expressed to the project personnel who performed the field operations at the four cities.

[5] *Triton X-155.*

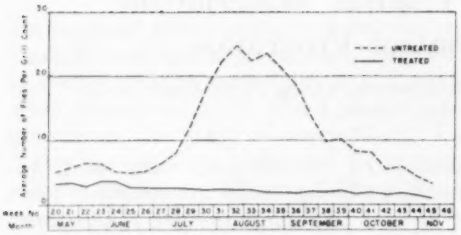

FIG. 1.—Fly densities in 1950 in treated low-class residential section, Charleston, West Virginia compared to those in untreated low class residential section, Dunbar, West Virginia. Based on a 3-week moving average.

Special problem areas such as dumps, abattoirs, rendering plants, vegetable and fruit packing establishments, and stock pens received complete coverage, the dosage being increased to 50 milligrams per square foot.

The general plan of treatment in a municipality consisted of an initial city-wide coverage in which the sequence of treatment was guided by the fly potential of the area or block. This coverage was followed by retreatment where necessary. Retreatment could consist of spraying an entire block or could be directed towards spot application within the block whenever fly densities were localized on individual premises.

Because of the extreme toxicity of dieldrin to warm-blooded animals, application and handling of the insecticide were performed by specially trained personnel in accordance with precautionary procedures recommended by the Technical Development Services of the Communicable Disease Center. These procedures required the use of protective clothing, rubber gloves, and respirators to mix the formulations; rubber gloves to handle the 6.25 per cent concentrate; avoidance of spray rebound by crew members; daily showering and twice weekly weight checks of mixing plant and spray crew personnel; immediate washing of any body surface wet by dieldrin; removal and routine laundering of protective clothing contaminated by spray; and special efforts to maintain leak proof equipment and to prevent the accidental exposure and poisoning of animals, particularly chickens.

Evaluation of the effectiveness of control was based upon measurement of adult fly densities by routine weekly grill surveys using the Scudder grill (1947). A 10 to 20 per cent weekly sample of the total number of blocks in the city was obtained by subdividing the community into 10 and 20 block units and conducting surveys in two blocks in each unit per week. Of the two blocks surveyed, one represented the block with the highest fly potential in the unit and was inspected every week (fixed station block). The identity of the second block (random station block) changed from week to week, its selection being determined by statistical methods. Occasionally, more intensive coverage was practiced in localized areas.

In the individual block appraisal, only the five highest grill counts obtainable were utilized in computing the block or grill average. Identification of flies was limited to the following species or genera: *Musca domestica*, *Phaenicia*, *Phormia*, *Sarcophaga*, *Ophyra*, *Stomoxys*, *Calliphora*, and *Callitroga*.

RESULTS.—Since a continuous effort was expended in effecting sanitational improvements at the Charleston, West Virginia, and Topeka, Kansas, projects, it is not possible to assign categorically the effective abatement obtained in these two cities to dieldrin alone, or to delineate the role that each of these measures played in the control picture. However, because of repeated occurrence of fly breeding in areas through these cities and the frequent need for insecticidal retreatments, it was obvious that the sanitation standards, although improved, still were not sufficient to account for the low fly densities which were obtained. This was particularly true at Charleston, West Virginia.

Throughout the season, the Charleston

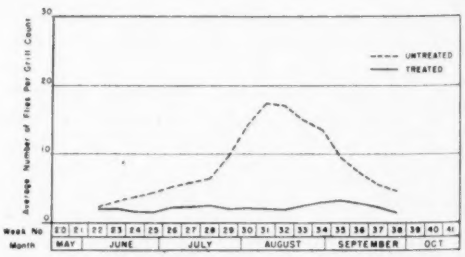

FIG. 2.—Fly densities in 1950 in treated low class residential section, Troy, New York compared to those in untreated low class residential section, Cohoes, New York. Based on a 3-week moving average.

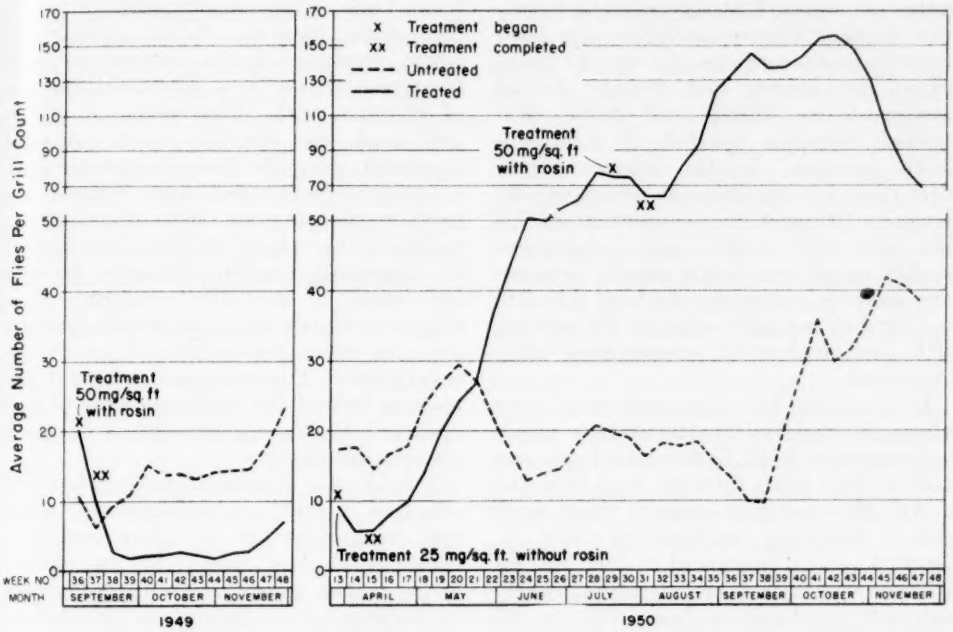

FIG. 3.—Effects of outdoor residual applications of dieldrin upon fly densities in a low class residential section (22 blocks) of Phoenix, Arizona compared to those in untreated Mesa, Arizona (10 blocks). Based on a 3-week moving average.

weekly grill indices reflected excellent control, densities rarely exceeding 2.5 flies per grill count in residential or business sections (Fig. 1). After treatment of the entire business section of 66 blocks in mid-June, no further applications were required in that section for 7 weeks. Based on the total blocks inspected during the period May to September, less than 6 per cent of the blocks in Charleston yielded averages in excess of five flies per grill count as compared to 56.3 per cent in the untreated towns. Only one of 3888 block inspections in Charleston revealed an average above 30 flies per grill count. Predominant flies in the Charleston area were blowflies of the *Phaenicia* group.

Results from Topeka likewise indicate effective control, weekly indices for all sections usually averaging less than 3.5 flies per grill count. Following a city-wide coverage in May and June, chemical treatment was restricted to a partial application in July with subsequent emphasis upon spot treatments of focal fly breeding sites. The prevalent species during the peak months of fly production was *Musca domestica*.

At Troy, New York, after application of a single residual spray in May and June 1950, further chemical and sanitation control operations ceased. Because of manpower limitations, full spray coverage was not effected over the entire city, but the business and low class residential sections received complete treatment, including larviciding of stranded fish carcasses along the river banks. Data reveal effective fly control for periods of 7 weeks in the business section and up to 3 months in the low class residential areas (Fig. 2). Blowflies of the *Phaenicia* group predominate in this region.

At the Phoenix, Arizona project, dieldrin was first used in the fall of 1949 in a preliminary test to determine its usefulness on a large scale basis. Data obtained from single premises-wide treatment at 50 milligrams per square foot in 234 blocks of a low class residential section indicated nine to eleven weeks of effective control of *Musca domestica*, the predominant species in the area (Fig. 3, 1949).[1] Results of supplementary tests in other parts of the city using 25 and 50 milli-

[1] Data portrayed refer to the special evaluative unit representing the 234 block area.

grams per square foot showed little difference in effectiveness; therefore, the 1950 recommendations called for the 25 milligrams per square foot dosage. Initial treatments in March and April 1950 yielded effective control of relatively short duration. In the business area, after complete coverage in mid-April, fly densities dropped to a minimum of 1.5 flies per grill count, but subsequent weekly counts showed a steady progressive increase, densities reaching 4.5, 6.0, and 12 flies per grill count in the second, fifth, and ninth weeks, respectively after treatment.

In the same low class residential area where the dieldrin treatment gave excellent results in 1949, little control was evident in 1950 when fly levels rose from 6.0 to 51.0 flies per grill count in the 9 week period following application (Fig. 3, 1950). A second treatment in July, using a 1.25 per cent rosin-based emulsion, merely reduced fly densities from 74.3 to 63 flies per grill count during and for 1 week following the period of application. Subsequent post-treatment densities for the next 4 weeks averaged 80, 92, 123, and 134 flies per grill count, respectively.

Because of this ineffectiveness of the dieldrin residuals, comparative tests using dieldrin (50 milligrams per square foot), chlordane (200 milligrams per square foot), and DDT (200 milligrams per square foot) were made in nine blocks selected to represent three types of problem areas, each reflecting a different socioeconomic and sanitational level. In the substandard area with exceptionally high fly population, periodic space spraying of adjacent blocks was invoked to prevent excessive infiltration into the test blocks. Results reveal that all three insecticides had negligible effect upon the fly population, regardless of the type of area in which applied.

By following adequate safety precautions a total of 59,467 gallons of 0.625 per cent and 1.25 per cent dieldrin emulsion was used to treat 114,909 premises in the four cities without any deleterious effects upon mixing-plant operators, spray crews, or other individuals or animals being noted.

DISCUSSION.—The previous data show dieldrin to be an effective chemical fly control measure at Topeka, Kansas; Charleston, West Virginia; and Troy, New York, while at Phoenix, Arizona, the same measure failed completely when employed for a second residual treatment. However a direct comparison of Phoenix with those cities in which treatment was effective is an unsound approach, since the Phoenix area presents a vastly different and more difficult fly problem than any one of the other municipalities. The species of flies, duration of fly breeding season, climatic factors, and extent of sanitation conditions conducive to fly breeding, all make Phoenix an area more productive of heavy fly populations. Thus an exploration of the reasons behind the ineffectiveness of this chemical at Phoenix in 1950 is of much greater significance.

Initially the failure of dieldrin to exert effective control in substandard areas was ascribed to the fact that treatment occurred during rising fly population levels in the spring as compared to the decreasing levels present in the fall of 1949. While this factor is of importance, subsequent findings point toward the development of definite dieldrin resistance in the house fly population. Field observation of the 1950 treatment first uncovered this resistance by noting the absence of spectacular knockdown and initial mortality during the spraying periods, as well as the finding of comparatively few "sick" flies at subsequent inspections. House flies were found to rest overnight on treated surfaces without any apparent detrimental effects. In substantiation of these observations, laboratory tests showed the Phoenix flies to possess a dieldrin resistance greatly exceeding that exhibited by the Pollard strain (March & Metcalf 1950). The rapid appearance of this resistance 6 months after the first residual application is of extreme importance, not only in regard to the particular project at which it appeared but also from the standpoint of the future significance of chemicals in fly control programs. The toxicity of dieldrin to *Musca domestica* during the initial tests gave hope that here was an insecticide which would surpass the DDT of 1945 in its efficacy against house flies. However, less than one year later this promising chemical was having no apparent effect upon *Musca domestica*. These results indicate the need for a shift from our present emphasis of screening

related chemicals for newer and more toxic compounds, to one of basic research on the physiological mechanism of fly resistance. By this approach the fundamental causes of fly resistance could be determined and remedial measures devised to prevent or counteract their development. In the final analyses, such investigation, although of a long term tenure, might well prove to be more fruitful and less costly than current screening techniques.

It is purely conjectural as to the future effectiveness of dieldrin at Charleston, West Virginia and Topeka, Kansas.[1] Since the predominant flies at Charleston are those in the *Phaenicia* group, which to date has not exhibited any resistance to chlorinated hydrocarbons, it may be postulated that continued successful fly control will prevail in that area. At Topeka, Kansas, where house flies comprise a high percentage of the fly densities, the chances of resistance occurring are greater but still by no means assured, since in certain south Texas areas subjected to 2 years of dieldrin applications resistance in *Musca domestica* has not been demonstrated.[2]

This inconsistency in the resistance picture makes it necessary to adopt a fluid policy in recommending chemicals for effective fly control, since the efficacy of the same insecticide has been shown to vary not only with the species of flies and the locality, but also the types of chemicals previously used in the area. Theoretically, rotation of insecticides might provide effective control; however, this is not advocated in face of evidence revealing that resistance apparently is not an isolated defense mechanism against one chemical, but a process which may induce cross-tolerances or more rapid development of resistance to other related insecticides.

As a general outlook, the unfavorable developments at Phoenix serve to re-emphasize forcibly to the public that the foundation of successful fly control is environmental sanitation. This basic tenet must be *accepted* and *practiced* by any community before sustained effective fly control can be achieved.

SUMMARY.—1. With the exercise of proper safety precautions, dieldrin has been employed as a city-wide residual treatment for fly control in four municipalities, each in the population range of 100,000 people, without any harmful effects upon the populace, domestic animals, or personnel involved in mixing, handling, and applying the insecticide.

2. As a supplement to sanitational measures at Charleston, West Virginia, and Topeka, Kansas, dosages of dieldrin at 25 milligrams per square foot (occasionally at rates of 50 milligrams per square foot at problem sites) were instrumental in providing successful control throughout the 1950 season. House flies predominated in Topeka, while at Charleston blowflies of the *Phaenicia* group were the prevalent species.

3. At Troy, New York, a single application of dieldrin at the rate of 50 milligrams per square foot yielded effective control of flies (predominately *Phaenicia*) for periods extending from 7 to 12 weeks.

4. At Phoenix, Arizona, where *Musca domestica* predominated, outstanding control was achieved in late 1949 with dieldrin, at dosages of 25 and 50 milligrams per square foot. Similar applications in 1950 failed spectacularly to suppress fly densities. Field observations and laboratory tests revealed the development of a high degree of dieldrin resistance in the house fly population, approximately 6 months after the initial exposure to this chemical. DDT and chlordane were likewise ineffective as residual applications.

5. The need for basic research on the physiology of the resistance mechanism is emphasized. Recommendations of chemicals for fly control must consider species of flies and locality or as well as the history of insecticidal usage in the area.

[1] Laboratory tests of two samples from Charleston, West Virginia, and one from Topeka, Kansas, in late summer indicated no development of resistance in the house fly population to date.

[2] Fay, R. W. and Doris P. Cullens (Unpublished manuscript) Laboratory studies of dieldrin resistance in the house fly, *Musca domestica*. Communicable Disease Center, Savannah, Ga.

LITERATURE CITED

March, R. B. and R. L. Metcalf. 1950. Insecticide resistant flies. Soap and Sanitary Chemicals **26:** 121–5, 139.

Scudder, H. I. 1947. A new technique for sampling the density of house fly populations. Public Health Reports **62:** 681–6.

SCIENTIFIC NOTES

Comparative Toxicity of Allethrin and Natural Pyrethrins

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The toxicities of allethrin and natural pyrethrins were compared on the basis of median lethal concentrations (LC-50) against the armyworm, *Cirphis unipuncta* (Haw.), the large milkweed bug, *Oncopeltus fasciatus* (Dall.), and the pea aphid, *Macrosiphum pisi* (Ktlb.), under laboratory conditions.

The materials used in these tests were allethrin, natural pyrethrum extract, and powdered pyrethrum flowers. The sample of allethrin was synthesized by chemists of the Bureau. The pyrethrum extract contained 8.05 per cent of pyrethrin I and 8.48 per cent of pyrethrin II in deodorized kerosene on a weight for weight basis. The powdered flowers contained 0.47 per cent of pyrethrin I and 0.46 per cent of pyrethrin II.

Dusts were made by diluting the materials to the desired concentrations with pyrophyllite. Required amounts of a concentrated allethrin and of powdered pyrethrum flowers were carefully weighed and thoroughly mixed with pyrophyllite in the proper proportions to give the concentrations needed.

For sprays or dipping purposes the concentrated extracts were diluted by forming an emulsion with acetone, which was then mixed with water. Since these mixtures were agitated while being used, the dispersion of the toxicants was reasonably satisfactory. All comparisons of toxicity are made on the basis of the active ingredient present.

TESTS AGAINST THE ARMYWORM.—Dusts were applied in a settling chamber to both surfaces of sections of selected barley leaves, the amount of deposit being determined by weighing an aluminum plate dusted at the same time. The leaf sections were fed to third-instar larvae in petri dishes. In spray tests barley leaves were thoroughly sprayed, allowed to dry, and then cut into sections and fed to third-instar larvae in petri dishes. Preliminary tests were made to determine concentrations necessary to kill, roughly, 30, 50, 70, and 90 per cent of the insects for dusts, and 25, 60, 70, and 90 per cent for sprays. Dust tests were replicated five times, spray tests six. Mortality counts were made approximately 48 hours after treatment. The results of these tests are presented in table 1.

Table 1.—Comparative toxicity of allethrin and natural pyrethrins in dusts and sprays to third instars of the armyworm.

Insecticide	Dusts		Sprays	
	Deposit of Active Ingredient per Square Centimeter	Mortality in 48 Hours	Concentration	Mortality in 48 Hours
	Micrograms	*Per Cent*	*P.p.m.*	*Per Cent*
Pyrethrins	0.25	89	20.2	65
	.21	64	9.7	57
	.17	53	4.8	25
	.085	34	—	—
	MLD .14	—	8.7	—
Allethrin	.75	92	125.0	68
	.625	81	62.5	51
	.50	53	31.25	17
	.25	38	—	—
	MLD .39	—	95.0	—

Table 2.—Comparative toxicity of allethrin and natural pyrethrins in dusts and dips to adult pea aphids.

Insecticide	Dusts		Dips	
	Deposit of Active Ingredient per Square Centimeter	Mortality in 48 Hours	Concentration	Mortality in 48 Hours
	Micrograms	*Per Cent*	*P.p.m.*	*Per Cent*
Pyrethrins	0.25	84	9.7	73
	.21	80	4.8	51
	.17	63	2.4	38
	.085	45	—	—
	MLD .111	—	4.2	—
Allethrin	3.0	75	62.5	89
	2.5	53	31.25	80
	2.0	51	15.6	45
	1.0	35	—	—
	MLD 1.573	—	16.0	—

On the basis of 50-per cent mortality values in dust tests, the natural pyrethrins were 2.8 times as toxic as allethrin, whereas in spray tests they were 10.9 times as toxic.

PEA APHID TESTS.—Adult pea aphids reared on Windsor bean plant leaves were dusted with allethrin and the natural pyrethrins in various dosages. Three dosages of each insecticide were similarly used in dipping tests. After the treatment the leaves were placed on uninfested potted Windsor bean plants Dust tests were replicated seven times, dipping tests five. Mortality counts were made approximately 48 hours after the treatment. The results of these tests are presented in table 2.

On the basis of 50-per cent mortality values in dust tests, the natural pyrethrins were about 14.2 times as toxic as allethrin, but in dipping tests they were found to be only 3.8 times as toxic.

Table 3.—Comparative toxicity of allethrin and natural pyrethrins sprays to fourth-instar nymphs of the large milkweed bug.

Insecticide	Concentration	Mortality in 48 Hours
	P.p.m.	*Per Cent*
Pyrethrins	120.7	91
	60.3	67
	30.17	27
	MLD 42.	—
Allethrin	62.5	98
	31.25	84
	15.6	42
	MLD 17.	—

MILKWEED BUG TESTS.—Fourth-instar nymphs of the large milkweed bug were placed in glass crystallizing dishes and sprayed until the dorsal surface was thoroughly wet. Untreated food and water were supplied during the 2-day test period. Four replicates were run.

Results of spray tests against the milkweed bug are presented in table 3.

On the basis of 50-per cent mortality values, allethrin was found to be 2.5 times as toxic as natural pyrethrins.

Parathion to Kill Fruit Fly Maggots in Cherries[1]

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The value of the cherry crop in Michigan for 1950 is estimated at 11 million dollars. Crop reports indicate that Michigan produces slightly more than one-half of the red tart cherries in the United States. The greater portion of the red tart cherry crop is processed. Michigan state law as well as federal laws are quite strict concerning the presence of any contaminants in processed cherries. The main offenders in this connection are the maggots of cherry fruit flies, *Rhagoletis* sp. The Michigan State Department of Agriculture maintains an inspection service to establish the extent of infestations in Michigan cherry orchards. Cherry crops infested with maggots of cherry fruit flies must be picked as soon as possible, and buried two feet below the surface of the ground with a covering of quicklime, or be destroyed completely by fire. This procedure, in addition to the crop loss, is very expensive and time consuming.

An important source of fruit fly infestation are the wild pin cherries, *Prunus pensylvanica* L. These occur throughout the cherry growing areas of Michigan. Repeated tests have shown that wild pin cherries are commonly heavily infested with maggots of cherry fruit flies.

In 1949, in an attempt to kill maggots in heavily infested pin cherries, tests were conducted with aldrin, dieldrin, and parathion. Additional tests were made in 1950. The test sites were located in Antrim and Charlevoix counties, Michigan. Groups of six trees were selected for each test, and when the fruit had ripened, the trees and the soil beneath them were thoroughly sprayed with an orchard sprayer working at 500 pounds pressure. Samples of fruit were picked from each test group, including unsprayed check groups, and were placed on screen wire suspended over pans of water containing formalin to collect any live maggots that emerged. In 1949, the test sprays were applied on August 2 and the samples of fruit were picked on August 9. The results of the 1949 tests are indicated in table 1.

Table 1.—Number of maggots in sprayed and unsprayed check samples of pin cherries in 1949.

Group	Insecticide	Ounces per 100 Gal. Water	Number of Maggots Emerging from Two Quarts of Fruit
1	Aldrin	16	115
2	Aldrin	8	228
3	Dieldrin	16	38
4	Dieldrin	8	77
5	Parathion (15%)	32	0
6	Parathion (15%)	16	7
7	Check No. 1	—	263
8	Check No. 2	—	237

[1] Approved for publication as Jour. article 1246 by the Director, Michigan Agricultural Experiment Station.

[2] Wallace E. Houk and Robert D. Harrison assisted in the work upon which the work herein reported is based. These men are both members of the Department of Entomology of Michigan State College.

Table 2.—Number of maggots in sprayed and unsprayed check samples of pin cherries in 1950.

Group	Ounces of Parathion, 15%, per 100 Gal. of Water	Number of Maggots Emerging from Two Gallons of Pin Cherries
1	16	1
2	32	0
3	48	0
4	Unsprayed	25
5	Unsprayed	34
6	Unsprayed	61

The data in table 1 indicate that parathion was the most effective material, that dieldrin gave some kill, and that aldrin was not effective.

In addition to tests on pin cherries in 1950, a test was conducted in a heavily infested block of Montmorency cherries. The number of trees in each test group and the spraying and maggot collection procedures for both the pin cherries and the Montmorency cherries in 1950 were similar to those used in the 1949 pin cherry tests. Since parathion was the most effective material in the 1949 tests, it was used exclusively in the 1950 tests. The sprays for these tests were applied on August 8 while samples of fruit were taken from the sprayed groups and their unsprayed checks on August 15. The results of the 1950 tests on pin cherries and on Montmorency cherries are indicated in tables 2 and 3, respectively.

Table 3.—Number of maggots in sprayed and unsprayed check samples of Montmorency cherries in 1950.

Group	Ounces of Parathion, 15%, per 100 Gal. of Water	Number of Maggots Emerging from 15 Pounds of Cherries
1	16	0
2	32	0
3	48	0
4	Untreated	1065
5	Untreated	535
6	Untreated	545

Tests with parathion in 1949–50 in Michigan indicate that 15 per cent Parathion, at amounts as low as 16 ounces in 100 gallons of water, is very effective in killing maggots of cherry fruit flies in both wild pin cherries and Montmorency cherries. These tests suggest a method of treating wild pin cherries to reduce chances of infestation in adjacent cultivated cherries. To orchardists who may be forced to destroy crops of maggot infested cherries, it offers the possibility of a cheaper and less time-consuming method of destroying maggots in infested orchards.

The possibility that parathion may kill other species of fruit fly maggots is suggested by these tests.

Prospaltella as a Secondary Parasite of Mealybugs

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Five males of *Prospaltella* were reared recently from parasitized specimens of the mealybug, *Pseudococcus nipae*, sent from Jamaica to California through the agency of the Commonwealth Institute of Biological Control.

Since usually in the genus *Prospaltella* the female is a primary parasite and the male is a secondary parasite of aleurodids and diaspine coccids, it is probable that with this Jamaican species the males developed hyperparasitically on the primary parasites inhabiting *P. nipae*.

A similar case was observed 27 years ago (Flanders 1924) when males of *Prospaltella* were commonly reared from codling moth eggs on walnuts. The circumstances under which this occurred indicated that the male *Prospaltella* was hyperparasitic on the early developmental stages of *Trichogramma*. About 3 per cent of 1297 codling moth eggs observed were parasitized and of these 92 per cent yielded *Prospaltella* instead of *Trichogramma*.

REFERENCE

Flanders, Stanley E. 1924. A new egg-parasite of the codling moth. JOUR. ECON. ENT. 17: 602.

Preliminary Insecticide-Fertilizer Soil Treatments[1]

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Woodle & Nettles (1950), while working with the sand wireworm in South Carolina, reported the control of the southern corn rootworm, the seedcorn maggot and other soil inhabiting insects by the application of 1 pound of chlordane per acre with the fertilizer. In Missouri considerable acreage of corn requires reseeding each year due to the grape colaspis damage to corn seeded on turned-under lespedeza sod. Planting of a test plot to study the effects of insecticide-fertilizer soil treatments for the control of the grape colaspis on corn grown on turned-under lespedeza sod was delayed until it was too late for grape colaspis damage. The small plot, however, was left for observation of the effects of the materials on the plants. The following insecticides were used at the rate of 1 pound per acre: chlordane, aldrin, dieldrin, heptachlor and lindane. Each insecticide was mixed with a 3-12-12 fertilizer and the fertilizer was applied at the rate of 200 pounds per acre.

The test plot with border rows on either side consisted of 21 rows of corn 100 feet in length. Three replications included a no treatment, fertilizer [(3-12-12) 200 lbs. per acre] and five insecticide-fertilizer treatments [(1 lb. per acre) plus fertilizer (3-12-12) 200 lbs. per acre]. The rows were opened with a hand plow and the treatments were applied with a hand operated fertilizer dispenser. The materials were then covered with dirt and seeded by planter with U. S. 13 field corn. All corn was given the usual side dressing of nitrogen of 66 lbs. per acre.

[1] Contribution from the departments of Entomology and Soils, Missouri Agr. Expt. Station, Journal Series No. 1272.

Throughout the first month there were striking differences between the height of corn in the no treatment, fertilizer and insecticide-fertilizer treated rows. Except in the Lindane treated plots, which were the same height as the fertilizer treated corn, the corn in the insecticide-fertilizer rows was taller, more uniform in height and looked much better. Chlordane, aldrin and dieldrin were judged the best of the five insecticide-fertilizer treatments during the first month. The corn in all of the insecticide-fertilizer treatments was more uniform in height than in the fertilizer or no treatment rows. During August all corn grew so well with the exception of the no treatment rows that only insignificant differences could be detected in the height of the corn in the various rows.

The corn was harvested early in November and the results are shown in table 1. The weight average of the corn in the three replications, the yield in bushels per acre and the shelling per cent average show no significant difference between the insecticide-fertilizer treatments and the fertilizer treatment. There was a significant difference between no treatment and fertilizer treatment and between no treatment and insecticide-fertilizer treatments.

Table 1.—Results in yields of corn when insecticides were added to the fertilizer.

TREATMENT	WEIGHT AVERAGE IN POUNDS	YIELD AVERAGE BUSHELS	SHELLING AVERAGE PER CENT
No treatment	45	67.5	75.8
Fertilizer	65	97.6	76.2
Fertilizer+ Chlordane	65	97.6	75.8
Fertilizer+Aldrin	69	103.5	77.9
Fertilizer+Dieldrin	67	100.5	77.9
Fertilizer+ Heptachlor	67	100.5	77.1
Fertilizer+Lindane	66	99.1	79.5

The amount of moisture available to the corn crop during July and August was above average. With ideal weather conditions for corn, the unthrifty plants which might have remained small and stunted grew well and made as good yields as the plants in the insecticide-fertilizer treatments.

The corn seedlings had been stimulated in the insecticide-fertilizer treated rows and during the first month had remained nearly a foot higher than those in the rows treated with fertilizer alone. All treated corn, however, finally yielded approximately the same amount of corn.

Five possible factors or combinations of factors have been suggested which might account for the increased size and uniformity of the corn seedlings in the insecticide-fertilizer rows. They are:

1. The death of usual root feeding and root pruning insects.
2. The reduced inoculation of the corn roots with harmful soil microorganisms upon the death of the root feeding insects.
3. The decrease or increase of soil microorganisms due to the presence of the insecticide.
4. A hormone effect caused by the insecticide which increased the number and size of corn leaves and roots.

5. The availability of additional plant nutrients brought about by a reaction of the insecticide on the soil.

Soil insecticides will have a definite place in agriculture. However, more information is required before they can be safely used in field crop rotations. As various varieties of plants react differently to the insecticides and as some of the insecticides remain active in certain types of soil for several years, our farm lands should not be heavily contaminated with these insecticides until more is known of their lasting qualities in the soil and their effects on plants, soil organisms and soil insects.

Tests with the Bowen Vat-Side Method for Determination of Toxaphene in Cattle Dips.[1]

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During 1949 several toxaphene emulsions were tested to determine their stability under severe and extended seasonal usage in cattle-dipping vats for the control of ticks. These tests were made by the Kerrville, Texas, station of the Bureau of Entomology and Plant Quarantine, in cooperation with the Hercules Powder Company, the Standard Oil Company of New Jersey, the Humble Oil and Refining Company, Wm. Cooper and Nephews, and ranchers in the vicinity of Beeville, Texas. These tests offered an excellent opportunity to study the merits of the vat-side method developed by Bowen (1950) for determining the concentration of toxaphene in the emulsion, which is known to change as dipping progresses during the season.

Under a repeated dipping procedure such as this, each grown animal that swims through the vat carries away approximately 1 gallon of dip. This loss of dip lowers the depth of the fluid in the vat, and sooner or later it must be replaced in order to provide ample depth for safe and complete submergence of the animals and also to bring the concentration of the emulsion back to its original level. Before the Bowen vat-side test was developed, the only way to determine the concentration of toxaphene left in the dip after it had been used for some time was by chemical analysis in the laboratory, which is not a practical method under operating conditions.

Samples of the dip emulsions were removed from each vat immediately after it was charged and subsequently after approximately every 300 cattle had passed through the emulsion. A portion of each sample was tested by the Bowen vat-side method, and later a duplicate portion was analyzed in the chemical laboratory as a check on the results obtained by the vat-side method. A simple plastic apparatus developed by the Standard Oil Company of New Jersey was used for making the vat-side tests. A similar apparatus was developed by Wm. Cooper and Nephews. This equipment, together with instructions for making the test, has recently been made available by each of these organizations, which have pioneered the toxaphene-dip industry in the United States.

[1] Presented at the meeting of American Association of Economic Entomologists at Denver, Colo., December 18–21, 1950.

[2] The authors acknowledge the valuable assistance of H. V. Claborn, chemist in the Bureau of Entomology and Plant Quarantine, and A. D. Lohr, chemist with Hercules Powder Company, in carrying out these investigations.

Table 1.—Per cent of toxaphene found in cattle dips by vat-side test and by laboratory analysis.

SAMPLE NO.	VAT-SIDE METHOD	LABORATORY ANALYSIS[1]
Formula 1		
1	0.45	0.47
2	.42	.44
3	.39	.39
4	.41	.41
5	.38	.41
6	.44	.49
7	.43	.42
8	.41	.41
9	.32	.36
10	.48	.48
11	.42	.42
12	.52	.49
13	.42	.45
14	.43	.46
15	.42	.44
16	.46	.46
Formula 2		
17	.46	.48
18	.34	.37
19	.24	.26
20	.50	.49
21	.46	.43
Formula 3		
22	.40	.44
23	.39	.43
24	.39	.41
25	.42	.42

[1] The analyses of samples 3, 4, 9, 14, 16, 19, and 22 were made by H. V. Claborn; all others were made by chemists of the Hercules Powder Company.

The time required to make the vat-side test with either apparatus depends on the degree of contamination or filth in the dip sample. If the sample is not filthy or muddy, the test should not require more than 10 to 15 minutes, but if the sample is full of filth and fine dirt, such as clay, it may take several hours to complete the test. The delay is due to the inability of the iso-octane to free itself from the dirty liquid and rise to the surface, which is necessary for obtaining a hydrometer reading. No accurate determination of the concentration of toxaphene in a dip can be made, either by the vat-side method or by chemical analysis, unless the emulsion remains stable in the vat or can be readily and completely resuspended.

Three emulsion concentrates were used in the tests described herein. Their percentage composition was as follows:

Formula 1:—Toxaphene 50, varsol (sp. gr. 0.793) 39.8, dimeric alkylated aryl polyether alcohol 4, phthalic glycol alkyl resin anhydrous 6, and epichlorohydrin 0.2.

Formula 2:—Toxaphene 65, range oil No. 1 (sp. gr. 0.817) 25, alkyl aryl polyethylene glycol 7.5, and alkyl lauryl sulfonate 2.5.

Formula 3:—Toxaphene 50, kerosene (sp. gr. 0.8015) 30, and alkyl aryl polyethylene glycol 20.

The percentages of toxaphene as determined by the two methods are given in table 1. The percentages found by laboratory analysis are based on the amount of organically bound chlorine.

In some of the vats that were subjected to heavy

use the dip became so dirty that it had to be removed and the vat recharged before the end of the tick season. In other vats where dipping was lighter the same dip was used throughout the season and remained in the vats through the winter for further use the following season. None of the formulations tested at Beeville disintegrated in the vat during the 1949 tick season, or until they had to be changed because of excessive contamination with manure and dirt, and those that were reactivated in the spring of 1950 were still in good condition in early summer when the tests were discontinued. Apparently there was no loss, or change, of the toxaphene in the emulsion while the vats remained inactive during the winter.

Since table 1 shows not more than 0.05 per cent difference between the two methods, it is evident that the Bowen vat-side test is a very reliable method for determining the percentage of toxaphene in emulsions in dipping vats. It appears that this test, made with the simple apparatus devised for this purpose, will give remarkably accurate results for dips made with concentrates variously formulated as long as the emulsions remain stable in the vats and can be readily and uniformly resuspended.

LITERATURE CITED

Bowen, C. V. 1950. A rapid vat-side test for assaying toxaphene in cattle dips. U. S. Bur. Ent. and Plant Quar. ET-285.

Typhus Control at Ports in Japan and Korea After World War II

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Although the notes presented in this paper were collected shortly after World War II it seems timely that they should be presented for publication in view of the present world situation.

Upon entering Japan after World War II the Allied Forces realized the importance of typhus control and knew that optimum conditions existed for dissemination of this dreaded disease. Two foci of infections were well known and feared. These were Korea and Hokkaido, Japan. The cities on the islands of Honshu and Kyushu had for the most part been heavily bombed. This created ideal conditions for the spread of the disease since people would migrate from place to place in search of housing and food. Not only this, there was the problem of repatriating millions of Japanese, including army, navy, and civilian personnel from all over the Pacific area to their homes. There were also great numbers of Koreans, Okinauans, Formosans and some Chinese who were scheduled to return to their native countries. With this vast movement of personnel the danger of typhus being spread from one country to another was ever present. The United States of America Typhus Commission was assigned the task of training personnel and setting up the disinfestation procedures. The writers were assigned the task at ports. The following ports in Japan were used for repatriation: Hakodate, Uraga, Nagoya, Maizuru, Tanabe, Kure, Senzaki, Shimonoseki, Fukuoka, Sasebo, and Kagoshima.

[1] Formerly with the USA Typhus Commission.
[2] M.D., Formerly Technical Sergeant with the USA Typhus Commission.

TRAINING.—Plans were made to visit all the ports at least once, and to reach both the Allied Personnel who were to supervise and the Japanese who were to do the work. It was soon discovered that one trip would not be sufficient since there was a constant change both of allied and Japanese personnel at most ports. The laborers who actually did delousing were frequently discharged or quit working on their own volition. Replacements were seldom given sufficient training to carry on the work efficiently. The work was very monotonous for many, and in several instances the importance was not fully understood. Thus, there was a tendency to do the work in a haphazard fashion. When this was discovered it was decided that the writers should travel constantly from port to port to train and retrain these operators. From early November 1945 to May 17, 1946 three round trips were made through the Islands of Honshu and Kyushu and two trips were made into Hokkaido.

At each port the technique for dusting personnel with DDT was demonstrated with both "hand" and "power" equipment. Instructions were printed in both Japanese and English. Even with these precautions the constant change of personnel hampered the quality of the work performed. With certain improvements the dusting technique was very similar to that outlined in TB MED 194. It was observed that certain steps were omitted, especially after long hours of operation. At some ports the authorities felt that the operators could not remember the many spots to dust. An attempt was made to overcome this by resorting to "assembly line" dusting. It was soon found that this method speeded up the processing operations, insured a more complete application of dust, distributed duties so that each operator was responsible for only one or two steps of dusting procedure, simplified training of operators and simplified supervision.

The operation technique varied slightly at the different ports, but the fundamentals were about the same. The various steps were approximately as follows:

(1) Individuals to be dusted were divided into two lines—one line for men and a second line for women and children.
(2) Individuals left baggage (if any) on platform where a person employed as duster applied DDT to extra clothing, blankets, etc.
(3) Individuals filed by duster in proper line, where each "duster" executed the step in the procedure for which he or she was responsible.
(4) Supervisors walked between lines of dusters, observed progress of work and made corrections.
(5) Individuals, when dusted, claimed their baggage and moved to another designated area, thence to their final destination.

Supervisors were always officers or enlisted men of the Allied Forces. Initially men were used to dust men, and women to dust women. It was soon discovered that Japanese women were much better workers and more dependable than Japanese men for routine work of this nature, and when possible were used entirely. A team of 10 to 12 dusters and a supervisor and one or two individuals to fill the dust guns could process from 400 to 600 individuals an hour.

SUPPLIES.—Initially there was no DDT for any of the southern ports, and even after DDT became available there was a shortage of typhus vaccine. By February 1, 1946 the supply situation had improved

to the extent that all persons could be vaccinated, and all repatriates and accompanying baggage could be dusted with DDT.

Operations in Korea were similar to those in Japan proper. The initial direction of delousing in Korea was done by Lt. Colonel C. M. Wheeler and Major A. D. Scoville. It was not possible for the writers to supervise repatriation in Korea due to a severe typhus epidemic in Osaka which demanded the attention of all available personnel trained in typhus control.

It is not the scope of this paper to discuss the various typhus epidemics in Japan proper but since the whole typhus control program was dependent on successful delousing, it does not seem out of place to mention them briefly. The Osaka epidemic is especially interesting since many of the smaller epidemics were traced to that city.

It is said that the epidemic in Osaka was traced to an individual who had gone to Korea to procure blankets for the black market. For his trouble he was confined to the Ikuno jail in Osaka where he became ill with typhus fever from which he later died. Several inmates of the jail also contracted the disease. Unfortunately a number of lesser criminals had served their sentence and were released. These individuals dispersed to various parts of the city taking their infected lice with them. Although every attempt was made to stop the epidemic it spread rapidly. Japanese doctors failed to report cases at the onset of symptoms. Typhus vaccines and DDT supplies were so short it became necessary to adopt a form of rationing or set up priority stations. The epidemic was finally broken but not until almost 7,000 cases had been reported. From February 16 to February 19 a total of 1,837,511 people were dusted with DDT.

During the next 14 days a total of 1,306,360 persons were dusted with 201,757 pounds of DDT. It was not possible adequately to supervise this work with the trained help available. Supervision was by 600 enlisted men and 60 officers of the 25th Division. These men were trained by Captain McLenmore Bouchelle and the writers. Over-all supervision was done by Major P. E. M. Bourland, Captain Bouchelle, Lt. Rafetta and the writers. Delousing in the area of Osaka where the largest number of cases occurred was supervised by the writers.

Many other epidemics in Japan during the spring of 1946 brought the reported cases up to almost 30,000. The death rate for these epidemics, which ranged from 7 to 10 per cent was lower than that reported in some other countries. The writers are of the opinion that many survived epidemic typhus only because they had been vaccinated prior to onset of symptoms. The writers do not have data to corroborate this statement, but many patients were known to get the disease shortly after vaccination and it appeared to the writers that with these cases the disease was never quite as severe and prognosis was usually good.

SURVEY.—The extensive travels of the writers throughout Japan, excluding the Island of Shokohu, presented ample opportunity for studying the lice populations. Body lice were found quite often but not comparable to the enormous infestations of head lice. From one end of Japan to the other approximately 85 per cent of the girls from 5 to 12 years of age had head lice. By the middle of April body lice in Osaka were rarely encountered and head lice were scarce. Young boys rarely had head lice since their hair was invariably clipped.

SUMMARY.—At 11 ports in Japan approximately 2,000,000 repatriates were processed up to April 1, 1946. The USA Typhus Commission was wholly responsible for training the personnel at these ports including both the Japanese civilians and the Allied Forces. Almost all ports were operating smoothly at the end of April and further difficulty was not encountered. Body lice among Japanese were fairly general but not as prominent as head lice. Approximately 85 per cent of young school girls had head lice.

A number of epidemics in Japan were reported by Scoville (1948). Almost 30,000 cases were reported for 1946 with a case fatality rate of 7 to 10 per cent. The town of Osaka alone, with a population of approximately 1,300,000 people had a total of approximately 7,000 cases.

LITERATURE CITED

Scoville, Addison. 1948. Epidemic typhus fever in Japan and Korea. Symposium on Rickettsial diseases of man. Amer. Assoc. Advancement of Science. Washington, D. C. Pp. 28–35.

Effectiveness of Insect Repellents Against Black Flies[1]

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As a part of an extensive insect-repellent testing program conducted by the Bureau of Entomology and Plant Quarantine from 1942 to 1945, a few miscellaneous tests were made against several species of black flies (Simuliidae). Some of these tests were made by the Orlando, Fla., laboratory and some by cooperators in other parts of the world. The results of tests made in Mississippi, in New York, and in Colombia (South America) are given in this paper.

The evaluation of all materials was based on the time from the application to the first bite and recorded as repellent time. Frequently it was necessary to terminate tests before bites were received. Where the repellent times for such tests exceeded the average of completed tests, they were included in the average. Such averages are marked in the table with a plus sign.

TESTS IN MISSISSIPPI.—Repellents were tested against the southern buffalo gnat, *Eusimulium pecuarum* (Riley), near Greenwood, Miss., in the spring of 1943. The tests were made on both man and domestic animals. On man $\frac{1}{4}$ teaspoonful was applied to the arms (elbow to wrist) and $\frac{3}{8}$ teaspoonful to the legs (knee to ankle). Animals were treated by applying a thin coating of repellent with a cotton swab or a hand sprayer at the rate of about 150 ml. per animal. Although this species does not readily attack man, bites were frequent before the repellents were applied, and on the untreated animals bites were too numerous to count.

As is shown in table 1, all the materials tested were effective for long periods on both man and animals; in fact, many of the tests had to be terminated before bites were received. The addition of

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Now with Cornell University.

Table 1.—Effectiveness against the southern buffalo gnat of repellents applied to man and livestock. Mississippi, 1943.

Repellents	Man		Livestock	
	Tests	Average Repellent Time	Tests	Average Repellent Time
	Number	*Minutes*	*Number*	*Minutes*
Citronella	5	564+	—	—
Ethanol, 2-(2-butoxyethoxy)-, acetate	7	431+	—	—
1,3-Hexanediol, 2-ethyl- (Repellent 6-12):				
Alone	12	564	8	334
Pyrethrins 0.25%+hendecenamide, N-isobutyl, 1%	2	585+	—	—
Pyrethrins 1%+hendecenamide, N-isobutyl, 2%	3	591+	—	—
dl-Malic acid, dibutyl ester	2	601+	—	—
Phthalic acid, dimethyl ester (dimethyl phthalate)	12	569+	9	399+
Phthalic acid, dimethyl ester with—				
Pyrethrins 0.25%+hendecenamide, N-isobutyl, 1%	2	594+	1	381
Pyrethrins 1%+hendecenamide, N-isobutyl, 2%	3	537	—	—
Repellent 6-12 10%+*Indalone* 10% (mixture 8-1-1)	8	560+	1	332
Repellent 6-12 20%+*Indalone* 20% (mixture 6-2-2)	6	522+	—	—
Repellent 6-12 33.33%+*Indalone* 33.33% (mixture 1-1-1)	9	542+	2	268
1,2*H*-Pyran-6-carboxylic acid, 3,4-dihydro-2,2-dimethyl-4-oxo-, butyl ester (*Indalone*):				
Alone	12	580+	9	466+
Pyrethrins 0.25%+hendecenamide, N-isobutyl, 1%	4	506+	—	—
Pyrethrins 0.25%	1	566+	1	396
Pyrethrins 0.25%+glycol, pinene ether, 2%	—	—	1	519+

pyrethrins, N-isobutylhendecenamide, or both, to the repellents did not seem to extend the repellent time.

TESTS IN NEW YORK.—Samples of the repellents dimethyl phthalate, Repellent 6–12, Indalone, and mixture 6-2-2 were sent to Robert Matheson, of Cornell University, who made a practical test in the Adirondack Mountains. *Prosimulium hirtipes* (Fries) and *Simulium venustum* Say were numerous enough to give up to 60 bites in a 10-minute exposure of untreated arms.

All the materials were effective for about 4 hours, in spite of rain and sweat. Indalone required more frequent re-treatment than the others, and dimethyl phthalate at times gave the best protection. The test subjects rated the materials in the following order of effectiveness: Repellent 6–12, mixture 6-2-2, dimethyl phthalate, and Indalone.

TESTS IN COLOMBIA.—Three repellents were tested in Villavicencio, Colombia, by Marston Bates. The right leg only of each subject was treated. The materials were applied several hours prior to exposures of 10 to 20 minutes in forested areas where black flies were abundant. The flies on each leg were counted, and the effectiveness of the materials determined from the difference in the number of bites on the treated and the untreated legs.

The results in table 2 show that Repellent 6–12 and dimethyl phthalate gave almost complete protection for 2 to 2.5 hours after application, but that Repellent 6–12 was superior after about 4 hours.

Table 2.—Effectiveness of three repellents against black flies in Colombia. 1943.

Repellents	Tests	Bites on Treated Leg	Repellency
	Number	*Number*	*Per Cent*
Exposures 2 to 2.5 hours after application			
Repellent 6-12	4	4	97
Dimethyl phthalate	2	1	97
Indalone	4	15	81
Exposures 4 to 4.5 hours after application			
Repellent 6-12	16	32	91
Dimethyl phthalate	8	17	89
Indalone	12	31	88

SUMMARY.—From 1942 to 1945 a few miscellaneous tests were made against several black flies (Simuliidae) by the Orlando, Fla., laboratory of the Bureau and by cooperators in other parts of the world. Against the southern buffalo gnat, *Eusimulium pecuarum* (Riley), in Mississippi selected repellents were effective for more than 7 hours on man and for more than 4 hours on livestock. The addition of pyrethrins to repellents did not seem to extend the repellent time. In the Adirondack Mountains of New York dimethyl phthalate, Repellent 6–12, Indalone, and a 6-2-2 mixture of these materials were effective for about 4 hours against *Prosimulium hirtipes* (Fries) and *Simulium venustum* Say. Against black flies in Colombia Repellent 6–12 and dimethyl phthalate gave almost complete protection for 2 to 2.5 hours; Indalone was less effective.

The Control of Body Lice on Prisoners of War at U. S. Ports During World War II

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During World War II the author was charged with the responsibility of setting up delousing facilities at 10 ports of embarkation in the United States and to assist personnel at the ports with

delousng procedures. Several papers have appeared by entomologists stationed at these various ports and by individuals responsible for the development of equipment used to fumigate the clothing of the prisoners. It seems timely to present some of the notes taken by the author during the early part of the war while he was engaged in this work.

It was known that German and Italian prisoners of war would be interned in the United States, and that some would be infested with body lice. Furthermore, it was anticipated that a portion of these prisoners originated in areas where epidemic Typhus had been reported. In order to prevent the spread of this disease it was thought necessary to disinfest the prisoners at the port of entry.

Conferences held in the Surgeon General's Office, Department of the Army, and the U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, culminated in research on fumigants as a substitute for steam in treating clothing. Past experience had proved that steam caused severe shrinkage to leather, webbing and woolens. After a few tests it was found that methyl bromide was the practicable fumigant to use. It should be borne in mind that this preceded later discoveries of MYL and DDT, developed by the Orlando Laboratory, U.S. Department of Agriculture for Army use.

Methyl bromide was discovered by a Frenchman named Le Goupil (1931) who reported this chemical to have insecticidal qualities. Shortly after his report Methyl bromide was tried in the United States and has since had wide use in agriculture. It has many advantages over other fumigants being rapid in action, non-injurious to clothing and equipment, effective at low temperatures, not too dangerous to handle and with little or no undesirable post fumigation residues or unpleasant odors. Prior to World War II, however, Methyl bromide had not been used for body lice control.

Three methods were developed for use in the Army. The individual bag, pit, and gas chamber methods. These have all been described adequately by Latta (1944), Latta *et al.* (1946), Richardson (1947), Stone and La Hue (1946). Stone and La Hue published considerable data on the effect of Methyl bromide on the control of body lice using an improvised vacuum chamber built from submarine buoys.

The first chambers built were made from plywood. These were satisfactory for agricultural use where low dosages and long exposures were practiced. For Army use, however, it was necessary to use high dosage and short exposures. The pressure created by the gas caused considerable leakage in the chambers built early in the war. Most of these were eventually condemned. Concrete and steel chambers were later built, but shortages of material delayed this phase to such an extent that one port never had a sufficient number to operate wholly with Methyl bromide. In this case steam was used to treat a part of the clothing.

The delousing procedure was the same at all ports. The prisoners disrobed and placed their clothing in bags which were fumigated for a period of 30 minutes at a dosage of 9 pounds of Methyl bromide per 1000 cubic feet. At temperatures below 60° F. the dosage was increased to 12 pounds per 1000 cubic feet. While the clothing was being fumigated the prisoners took showers, were given a health inspection and the hairy parts of the body were sprayed with a delousing insecticide.

When fumigated the clothing was returned to the prisoners who shook them out and dressed. It was soon found that the accumulation of Methyl bromide fumes in the dressing rooms was beyond the safety limits of 30 parts per million, (Houghton (1946)). It was necessary to install ventilation equipment at a time when both motors and steel products were extremely hard to get.

Approximately 500,000 prisoners of war, both German and Italian were processed, the majority of these at Boston, New York, and Hampton Roads At the close of the war there was ample steam and Methyl bromide equipment to handle all disinfestation. It was estimated that from four to six thousand prisoners could be processed each hour. It is not known whether any infected lice ever came to the port but there is no record of any epidemic typhus having been spread from the prisoners disinfested at U. S. ports.

SUMMARY.—Ten ports of embarkation were equipped during World War II for disinfesting prisoners of war. For the most part Methyl bromide fumigation was used to treat the clothing, but steam was also used at one port. Approximately 500,000 prisoners were disinfested during the war. There is no record of any typhus cases being spread by these prisoners in the United States.

LITERATURE CITED

Anonymous. 1945. Disinfestation procedures. War Department Tech. Bull. TB MED 194 July 1945. Washington, D.C., U.S. Govt. Printing Office.

Houghton, J. A. 1946. Determination of halogenated hydrocarbons in air. Bul. US Army M. Dept., 5: 220.

Latta, Randall, 1944. Methyl bromide for the delousing of troops. JOUR. ECON. ENT.: 37: 103.

Latta, Randall, Henry H. Richardson, and James B. Kindler. 1946. Methyl bromide as a delousing agent. Circ. No. 745, April 1946, U.S.D.A.

Le Coupil, M. 1932. Les proprietes insecticides du bromure de methyl. Rev. Path. Veg. et Ent. Agr. 19: 169–72.

Richardson, Henry H. 1947. Methyl bromide delousing, DDT insecticide and rodent control problems at New York Port of Embarkation. Bul. US Army M. Dept., 7 308–16.

Stone, Philip C., and La Hue, Delmon W. 1946. Rapid vacuum fumigation of the body louse with methyl bromide. JOUR. ECON. ENT. 39: 581–8.

Potato Psyllid Selection of Host Plants

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Host-plant studies of the potato psyllid, *Paratrioza cockerelli* (Sulc), which were started at Scottsbluff, Nebr., in 1939, have indicated that the adult psyllid selects certain plants of the nightshade family over others upon which to deposit eggs. Daniels (1934), List (1939), and Swenk & Tate (1940) have shown that wild solanaceous plants which start growth early in the season are important hosts of the psyllid and that, where potato and tomato crops later become available psyllids move from the wild hosts to these crops and cause them to develop the disease known as psyllid yellows.

According to List (1939) and Daniels (1934), the preferred host plants of the potato psyllid belong to the nightshade family, and perennial groundcherries are important host plants early in the spring and late in the fall. Swenk & Tate (1940) state that in Nebraska species of the nightshade family are preferred, that potatoes and tomatoes are particularly favored, and that some of the perennial groundcherries, such as the prairie groundcherry, *Physalis lanceolata*, and the long-leafed groundcherry, *P. longifolia*, are favored host plants in the early spring before tomatoes or potatoes are available. They further state that buffalo-bur, which occurs abundantly in potato-growing sections, is susceptible to psyllid attack and is an important factor in the propagation of psyllids.

Tests were conducted at Scottsbluff from 1941 to 1945, inclusive, to determine the host-plant preference of the adult potato psyllids among the common wild and cultivated plants of the nightshade family in the Colorado-Wyoming-Nebraska area. Egg counts were used as an indication of adult selection of host plants.

The plants were grown in small plots, each consisting of 6 rows 18 feet long. Samples of the leaves were taken at weekly intervals and examined for eggs. The samples constituted about the same area of leaf surface for the different plants; for example, 50 leaves were taken from small-leafed plants, 50 leaflets from potato and tomato plants, and 50 sections about the size of potato leaflets from leaves of large-leafed plants such as eggplant and tobacco. The examinations were begun as soon as the plants were growing well, usually about July 15, and continued until the plants were killed by frost.

Table 1 shows the mean egg counts on plants of the Solanaceae on which records were made each year from 1941 to 1945.

An analysis of variance showed that there were significantly more eggs on Chinese lantern and horsenettle than on any of the other plants, and more on cultivated groundcherry and wild groundcherry, *Physalis lanceolata*, than any of the remaining plants.

Chinese lantern is an annual, cultivated ornamental plant, which is grown to a very limited extent. Therefore, it will be of little importance as a source of breeding of the potato psyllid. Horsenettle is a perennial wild plant, which reproduces by seed and underground rootstocks and occurs abundantly in many sections of the Western States. Therefore, it can be classed as an important plant upon which the psyllid could multiply and spread to potato and tomato crops. The groundcherry, *Physalis ixocarpa*, is an annual cultivated to a limited extent and therefore of little importance. On the other hand the wild groundcherry, *P. lanceolata*, is a perennial which is widely scattered over the Western States, and will therefore serve as a host plant to psyllids that move to potato and tomato crops.

Table 2.—Numbers of potato psyllid eggs per sample on host plants of the Solanaceae family on which incomplete counts were made for 1 to 3 years.

Host Plant	Average
Husk tomato, *Physalis pruinosa* L.	65.4
Nicandra physaloides (1) Gaevtn.	57.3
Nierembergia hippomanica Miers	46.0
Jimsonweed, *Datura stramonium* L.	37.9
Wild groundcherry, *Physalis longifolia* Nutt.	14.0
Pimento pepper, *Capsicum frutescens* L.	7.3
Flowering tobacco, *Nicotiana* probably *affinis* T. Moore	4.5
Tabasco pepper, *Capsicum frutescens* var. *conoides* (Mill.) Bailey	4.4
Cultivated petunia, *Petunia* sp.	0

Table 1.—Average numbers of potato psyllid eggs per sample on plants of the Solanaceae family that were examined over the 5-year period 1941–45.

Host Plant	1941	1942	1943	1944	1945	5-Year Average
Chinese lantern, *Physalis francheti* Mast.	106.0	105.0	22.4	56.0	143.4	86.6
Horsenettle, *Solanum carolinense* L.	79.5	143.0	18.8	12.0	96.6	70.0
Cultivated groundcherry, *Physalis ixocarpa* Brot.	35.3	20.3	5.2	47.2	22.6	26.1
Wild groundcherry, *Physalis lanceolata* Michx.	12.3	17.0	0	45.2	12.1	17.3
Buffalo-bur, *Solanum rostratum* Dunal	18.0	20.3	0	14.5	15.6	13.7
Tomato, *Lycopersicon esculentum* Mill.	21.0	.3	0	15.3	23.6	12.0
Matrimony-vine, *Lycium halmifolium* Mill.	8.7	4.0	0	36.4	7.4	11.3
Black nightshade, *Solanum nigrum* L.	15.3	9.3	2.4	11.0	10.4	9.7
Wild tomato, *Solanum triflorum* Nutt.	24.7	3.8	1.6	9.5	1.3	8.2
Bell pepper, *Capsicum frutescens*, var. *grossum* (L.) Bailey	15.5	7.0	0	9.8	4.8	7.4
Ornamental pepper, *Capsicum frutescens* L.	16.5	8.8	0	4.3	2.3	6.4
Potato, *Solanum tuberosum* L. (Bliss Triumph variety)	3.8	4.3	0	11.7	5.0	5.0
Tobacco, *Nicotiana tobacum* L.	10.5	5.5	0	4.5	1.6	4.4
Eggplant, *Solanum melongena* L.	0	3.3	.8	3.5	1.8	1.9

On some additional plants of the family Solanaceae data were obtained for only 1 to 3 years because of the difficulty in propagating them. These plants and the average counts for each are shown in table 2.

These data indicate that husk tomato, *Nicandra physoloides*, *Nierembergia hippomanica* and jimsonweed are also preferred over many of the commonly occurring plants, and particularly over the principal economic host plants, potato and tomato. The husk tomato, *Nicandra physaloides* and *Nierembergia hippomanica* are grown to a limited extent, and jimsonweed, a wild plant, does not occur abundantly in this area.

LITERATURE CITED

Daniels, Leslie B. 1934. The tomato psyllid and the control of psyllid yellows of potatoes. Colo. Agr. Col. Bul. 410.

List, George M. 1939. The potato and tomato psyllid and its control on tomatoes. Colo. Expt. Sta. Bul. 454.

Swenk, Myron H., and Tate, H. Douglas. 1940. The potato flea beetle and the potato psyllid in Nebraska. Neb. Agr. Expt. Sta. Bul. 327.

Zinc Ethylene Bisdithiocarbamate[2] Toxic to Pickleworm and Melonworm

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Genung (1949) reported that zinc ethylene bisdithiocarbamate[2] apparently greatly reduced populations of the melonworm, *Diaphania hyalinata* (L.), and the pickleworm, *D. nitidalis* (Stoll), when applied in the early part of 1949 on late cucumbers in the Lake Worth area of Florida for control of powdery and downy mildews. He obtained additional evidence along this line in the early part of 1950 (unpublished correspondence). His findings are substantiated by observations made by the writer during the fall of 1950 in the vicinity of Charleston, S. C.

Applications of a fungicide were found to be necessary on plantings of cucumbers and squash used in insect control experiments during several years prior to 1950 at Charleston, S. C. Copper compounds were used for that purpose from 1930 to 1934 and zinc dimethyl dithiocarbamate[3] in 1948 and 1949. Zineb was used on the experimental plantings for the first time in 1950, and evidence was obtained that it gave some control of the pickleworm. Infestations of this insect that developed on the check plots (those treated only with Zn−1) were much lighter than those that prevailed on check plots in each of the other years. Furthermore, several insecticides that were relatively inferior against the insect in previous years gave adequate control in the 1950 experimental plantings. Zn−1 was applied to some extent on commercial plantings of cucumbers in the Charleston area prior to 1950 and was used almost exclusively on this crop in 1950. In general, commercial growers found the pickleworm less difficult than usual to control during 1950.

Zn−1 usually was applied weekly to the 1950 experimental and commercial plantings, either as a 4-per cent dust, at the rate of 25 to 30 pounds per acre, or as a spray containing 2 pounds of a 65-per cent wettable powder in each 100 gallons, at the rate of 50 to 75 gallons per acre.

Relatively low night temperatures during the last week of September and the first half of October may have reduced oviposition of pickleworm moths to some extent in 1950. The presence in the area of a moderate infestation of the insect in an abandoned planting (which received no fungicide or insecticide after the plants produced flowers) indicated, however, that weather was not the chief factor responsible for the lower-than-usual 1950 populations.

When it became evident that Zn−1 might be responsible for keeping the pickleworm population at a low level in the 1950 plantings, an attempt was made to get more definite information on the subject. Two brands of Zn−1 were tested in laboratory cages and also on small field plots in a late planting of Yellow Crookneck squash In the laboratory 3.9-per cent Zn−1 dusts were applied to the insects at an average dosage (about 20 pounds per acre) or a heavy dosage (about 40 pounds per acre). The mortality of fourth-instar larvae that followed the use of Zn−1 at these rates was 50 and 60 per cent, respectively, for brand A, and 35 and 50 per cent for brand B. No fifth-instar pickleworms were killed by heavy dosages of either brand.

In the field the two brands of Zn−1 were compared with lindane and with untreated checks on each of five randomized-block replications in small field plots. Each plot consisted of three hills, each of which usually contained two squash plants. Four spray applications, each at approximately 80 gallons per acre, were made at intervals of 5 to 7 days between November 2 and 20. The sprays were applied with a knapsack sprayer that developed a fairly constant pressure of about 75 pounds. Cloth barriers held at the ends of each plot prevented insecticide drift.

The plants produced few fruits because they were stunted when small by excess rain and because they were grown so late in the fall. Therefore, results were based on the number of surviving larvae in the staminate flowers (a favorite location of the insect) during 8 counts and on the entire plants during a count at the end of the experiment. A total of 130 flowers were examined during the first 3 counts (1

Table 1.—Number of pickleworm and melonworm larvae surviving on small field plots of cucumbers sprayed with lindane or Zn−1. Charleston, S. C., November, 1950.

Insecticide	Dosage (Pounds per 100 Gallons of water)	Pickleworms			Melonworms
		Counts 1 to 3	Counts 4 and 5	Counts 6 to 9	All counts
Lindane (25% wettable powder)	1	45	0	0	2
Zn #1 (65% wettable powder)					
Brand A	2	112	21	17	8
Brand B	2	107	21	31	12
Check (untreated)		95	33	61	14
Minimum significant difference:					
At 5% level		31.9	8.2	22.9	
At 1% level		44.8	11.6	32.1	

[1] In cooperation with the South Carolina Agricultural Experiment Station. Acknowledgments are made to F. P. Cuthbert who assisted in these studies.

[2] *Zineb* = "Zn−1".

[3] *Ziram* = "Zn−2."

and 4 days after the first application and 1 day after the second application), 50 flowers during counts 4 and 5 (3 and 6 days after the second application), and 75 flowers during counts 6, 7, and 8 (2, 5, and 7 days after the third application).

Table 1 shows that both brands of Zn−1 reduced the pickleworm population gradually. Differences between the two products were not significant. Lindane proved superior to both lots of Zn = 1, giving complete control of the pickleworms in the flowers after the second application.

Only a few melonworms were present on the squash in the field plots. The Zn−1 sprays were less toxic to these larvae than lindane, but slightly reduced the number of melonworms in the flowers. This species usually feeds on the foliage of plants.

Few squash fruits became large enough to harvest because of low night temperatures and injury to the plant roots by excess rain. The fruits grew slowly and therefore were subject to pickleworm attack much longer than the fruits that develop earlier in the fall. Lindane reduced the number of wormy squash by about 63 per cent. The two Zn−1 products had no apparent effect on the fruit infestation. Materials that are only partially effective against pickleworms often do not kill enough larvae to protect the fruit.

Further studies of Zn−1 are needed in this connection and, as pointed out by Genung (1949), entomologists should keep in mind the possible insecticidal action of Zn−1. This also is true in the case of plant pathologists.

Literature Cited

Genung, William G. 1949. Dithane dust indicates effective control of melonworm and pickleworm. Fla. State Hort. Soc. Proc. **62**: 130–2.

Hemisarcoptes malus, a Predator of Forbes Scale

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In examinations of Forbes scale, *Aspidiotus forbesi* Johns., collected in an unsprayed orchard near Vincennes, Indiana, during June 1950, two or three mites were found under the shells of each of numerous scales. Dark spots, where the mite apparently had probed the scale bodies, were present on the adults, many of which were dead and drying up. Specimens of the mite were identified by E. W. Baker, Division of Insect Identification, as *Hemisarcoptes malus* (Shimer) Kept. This establishes Forbes scale as one of the hosts for this mite.

Ewing (1912), Hewitt (1917), Tothill (1918) and Laid (1949) have reported this mite as an important predator of oystershell scale, *Lepidosaphes ulmi* (L.), stating that it feeds on the eggs under the scale coverings. Andre (1942) reported that this mite is predaceous on San Jose scale, *Aspidiotus perniciosus* Comst., in France. Baker *et al.* (1943) reported it as predaceous on the Chinese obscure scale, *Parlatoria chinensis* Marl., in Missouri.

Inasmuch as crawlers and live specimens of scale were difficult to find in the unsprayed orchard and the mites were plentiful, it seems probable that this predator was contributing extensively to the control of Forbes scale.

Tothill (1918) lists the distribution for *Hemisarcoptes malus* as Illinois, Iowa, Massachusetts, Ohio, and several provinces in Canada. Cooley (1912) refers to its presence in Montana.

Literature Cited

Andre, M. 1942. Sur. *l' Hemiscarcoptes malus* Shimer. Bul. Mus. Nat. Hist. Nat. (2) **14**(3): 173–80. (Abstract in Rev. Appl. Ent., Ser. A, **33**: 357.)

Baker, Howard, Nathan Stahler, A. C. Johnson, Lloyd Adams, and R. C. Froeschner. 1943. *Palatoria chinensis* Marlatt, U. S. Bur. Ent. and Plant Quar. E-595.

Ewing, H. E., and R. L. Webster. 1912. Mites associated with oyster-shell scale (*Lepidosaphes ulmi* Linne). Psyche. 121–34.

Hewitt, C. G. 1917. Natural control of insects. Canada Dept. Agr. Dominion Ent. Rpt. 1917: 8–9.

Laid, F. T. 1949. The influence of spray programs on the fauna of apple orchards in Nova Scotia: II Oystershell scale, *Lepidosaphes ulmi* (L.). Canad. Ent. **79** (1947): 196–209.

Tothill, John D. 1918. The predaceous mite *Hemisarcoptes malus* Shimer and its relation to the natural control of the oyster-shell scale, *Lepidosaphes ulmi*, L. Agr. Gaz. Canada **5**: 234–39.

Technique in Jarring for Plum Curculio[1]

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Jarring trees to obtain plum curculio adults is an old and well established practice. It was considered at one time as a valuable supplementary control measure for plum curculio on peaches. Although no longer practiced as a control measure it is still considered a valuable tool particularly in research. Jarring is useful as a means of timing spray applications and for locating areas of heavy infestation. It may also be used as a criterion for evaluating effectiveness of spray applications.

Equipment and technique for jarring are described in this paper. The method described has been used with satisfactory results during 1949 and 1950 in the peach belts in the Arkansas River valley centered around Clarksville and in the southwestern belt near Nashville.

The sheet used in experiments in Arkansas is 4 feet by 7 feet and is attached to a light wooden frame. The frame is hinged for folding to facilitate transporting from one orchard to another. Other equipment includes a light rubber covered mallet and a small bottle fitted with a slit rubber top for collecting the beetles.

[1] Research paper No. 1021, Journal Series, University of Arkansas. Published with the permission of the director of the Arkansas Agricultural Experiment Station.

The procedure involved in using the small jarring sheet is to hold the sheet in one hand and to jar limbs by one or two sharp blows with the mallet. No attempt is made to jar an entire tree. The beetles are usually collected at the end of the jarring period. If, due to high temperature, the beetles become active, they are captured and counted immediately. The unit of measurement of curculio abundance is based on the amount of time spent jarring. In most cases a period of 5 minutes is used. If a complete record in an area is desired, four units of 5 minutes each are taken. Usually the limbs on one side of a tree are jarred and the operator then moves on to the next tree.

The principal disadvantage in using a small sheet to jar for 5 minute periods seems to be that it has been customary to think of curculio populations as the number per tree. Since this number is an arbitary figure and is at best only an approximation, a different unit of expressing density of population should be equally satisfactory. The number of limbs jarred in 5 minutes by different individuals will undoubtedly vary somewhat, but this variation should not be nearly so great as the differences between individual trees.

In the past jarring records have been on the basis of the number of curculios obtained per tree. This system has numerous disadvantages. The size of trees varies greatly from one orchard to another because of differences in age and growing conditions. Curculio population varies greatly among trees of fairly uniform size. This necessitates a large sample to obtain representative data. It is difficult to jar an entire tree especially if it is a large one. Unless considerable labor is available the sheets must be placed on the ground. Uneven terrain and weed growth make this impractical in many orchards.

During the summer the temperature is too high in Arkansas for satisfactory jarring during most of the daylight hours. The beetles are more active and many of them fly upon being disturbed. More records can be taken during that period of the day when conditions are favorable if the small sheet is used to jar individual limbs rather than jarring entire trees. Also the small sheet can be held close to the limbs where the curculios are located. Fewer beetles will fly before hitting a sheet held close to the limbs than one on the ground. Also more beetles can be recovered from the sheet on a rigid frame since they can be removed more quickly from it than from large sheets. Thus jarring can be done with the small sheet when high temperature would make the use of large sheets on the ground impractical.

Sheets sufficiently large to cover the area under a large peach tree require several persons to hold them. The only alternative is to place them on the ground. In many Arkansas orchards the terrain is too rough to place the sheets on the ground satisfactorily. With the sheets on the ground it is difficult to jar the tree without walking on the sheets. If they are placed on bare ground they soon become soiled making it difficult to locate the curculios on them. The small sheet on a frame eliminates these difficulties.

The advantages of considering the number of curculios jarred in a 5 minute period, using a small sheet on a rigid frame as the unit of measurement, may be summarized as follows: Only one person is needed to take the records. More records can be taken in the same time. Difficulties due to variations in tree size, unevenness of terrain, and high temperature are decreased or eliminated.

New Host and Distribution Records for *Amblyomma inornatum*

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There has not been a great deal of published information relative to *Amblyomma inornatum*, since it was described by Banks in 1909 (Proc. Ent. Soc. Wash., 10: 170–173) from the dog (Nueces Co., Tex.) and the rabbit (Kleberg Co., Tex.). Cooley and Kohls in 1944 (Jour. Parasit., 30(2): 77–111) record a male and female from rabbits, Kingsville, Tex., a male from a jackrabbit, Kingsville, four males and one female from a coyote, Kingsville, and two females from a cow, Victoria, Tex. Four males and two females, host unknown, Muzquiz, Coahuila, Mexico, were previously reported by Cooley and Kohls (1939) as *A. philipi* (Pub. Health Repts., 54(2): 44–47). Eads in 1948 (Jour. Mamm., 29(3): 268–327) lists one from coyote, Refugio Co., Tex. Brennan (1945) reports one *A. inornatum* from jackrabbit in Bexar Co., Tex. (Tex. Repts. Biol. and Med., 3: 112–121). Tovar in 1944 reported this species from "rabbits and hares"; Otastepec, Morelos, Mexico (Rev. Inst. Salub. Enfer. Med. Trop. 5: 293–295).

The following *Amblyomma inornatum* records have resulted from Texas ectoparasite studies conducted by this Department: one female *ex* javelina, *Tayassu angulatus*, Nueces Co., June 15, 1943, coll. R. B. Eads; three females and two males *ex* jackrabbit, *Lepus californicus*, Duval Co., Aug. 6, 1947, coll. R. B. Eads and R. W. Strandtmann; one female *ex* dog, Jim Wells Co., Aug. 12, 1947, coll. Mrs. R. A. Albert; two females and one male *ex* pack rat, *Neotoma micropus*, Cameron Co., Aug. 7, 1947, coll. R. B. Eads and R. W. Strandtmann; one male *ex Neotoma micropus*, Bee Co., Aug. 12, 1948, coll. J. L. Regan; nine *ex* cottontail rabbit, *Sylvilagus floridanus*, Bee Co., Aug. 6, 1947, coll. J. L. Regan; one female *ex* cotton rat, *Sigmodon hispidus*, Presidio Co., June, 1948, coll. J. L. Regan; one female *ex* coyote, *Canis latrans*, Zavala Co., Oct. 20, 1950, coll. O. L. Walker; three males *ex* skunk, *Mephitis mephitis*, Zavala Co., Sept. 28, 1950, coll. C. W. Johnson and O. L. Walker; two males *ex* armadillo, *Dasypus novemcinctus*, Uvalde Co., Oct. 10, 1950, coll. C. W. Johnson and O. L. Walker; two females *ex Mephitis mephitis*, Zavala Co., Nov. 6, 1950, coll. C. W. Johnson and O. L. Walker; one female *ex* wolf, *Canis niger*, Bee Co., Feb. 24, 1950, coll. J. P. Forgason, seen through the courtesy of J. A. Deer.

In the interest of completeness, Glen M. Kohls kindly supplied the following Rocky Mountain Laboratory records of *Amblyomma inornatum:* seven males and four females *ex* coyote, Jim Wells Co., July 7, 1944, coll. Richard Albert, sent to R. M. L. by R. W. Strandtmann; three males and four females *ex* dog and cat, Jim Wells Co., Tex., 1943, coll. R. Albert, submitted to R. M. L. by R. W. Strandtmann; two males and two females *ex* roadrunner, *Geococcyx californianus*, Jim Wells Co., Sept., 1945, coll. Mrs. Richard Albert, submitted to R. M. L. by R. W. Strandtmann; six males and two females *ex* armadillo, Hidalgo Co., Tex., Aug. 9, 1935, coll.

[1] The assistance of Mr. G. C. Menzies and Mr. B. G. Hightower in securing the information presented in this note is acknowledged by the author.

S. D. Mulaik submitted to R. M. L. by Lafe Edmunds, Feb. 24, 1948; two males and two females *ex* bobcat, *Lynx rufus*, Bee Co., Tex., July 12, 1940, coll. J. A. Deer, submitted to R. M. L. by M. A. Price; five males and three females, *ex Citellus* sp., Culiacan, Sinaloa, Mexico, received by R. M. L. April 2, 1946.

Remarks. Previously unrecorded hosts of *Amblyomma inornatum* are: the roadrunner, *Geococcyx californianus;* the armadillo, *Dasypus novemcinctus;* the pack rat, *Neotoma micropus;* the cotton rat, *Sigmodon hispidus;* ground squirrel, *Citellus* sp.; the javelina, *Tayassu angulatus;* the skunk, *Mephitis mephitis;* domestic cat; the bobcat, *Lynx rufus;* and the wolf, *Canis niger*. The Texas Counties of Presidio, Uvalde, Zavala, Bee, Duval, Jim Wells, Cameron and Hidalgo represent new United States distributional records.

The armadillo is not only a new host for *Amblyomma inornatum*, but there has been but one previous United States tick record known to us from this animal. Brennen in 1945 (Tex. Repts. Biol. and Med. 3(2): 204–226) reports two *Amblyomma americanum* nymphs from two immature armadillos at Camp Bullis, Tex.

LITERATURE CITED

Banks, Nathan. 1909. Three new ticks from the United States. Proc. Ent. Soc. Wash., **10**: 170–3.

Brennan, J. M. 1945a. Field investigations pertinent to Bullis fever—preliminary report on the species of ticks and vertebrates occurring at Camp Bullis, Texas. Texas Repts. Biol. and Med. **3**(1): 112–21.

Brennan, J. M. 1945b. Field investigations pertinent to Bullis fever—the lone star tick, *Amblyomma americanum*. Texas Repts. Biol. and Med. **3**(2): 204–26.

Cooley, R. A. and Kohls, G. M. 1944. The genus *Amblyomma* (Ixodidae) in the United States. Jour. Parasit. **30**(2): 77–111.

Eads, R. B. 1948. Ectoparasites from a series of Texas coyotes. Jour. Mamm. **29**(3): 268–71.

Tovar. 1944. Rev. Inst. Salub. Enfer. Trop. **5**: 293–5.

REVIEWS

THE COLLEMBOLA OF NEW YORK STATE, by Elliott A. Maynard. Comstock Publishing Company Inc. Ithaca, New York. 1951. 339 pp. with illustrations. Price $7.50.

Although the Collembola have not been incriminated as primary pests in many instances, one, the garden springtail, *Bourletiella hortensis*, has distinguished itself sufficiently to be listed in the Common Names of Insects Approved by the American Association of Economic Entomologists, and others have been shown to be inimical to man's interest in numerous ways. The small size and secretive habits of these primitive insects (or specialized non-insects) may have something to do with this state of affairs.

Despite this apparent dearth of economic importance, the Order is an intriguing one and has at one time or another attracted the attention of almost every professional entomologist. Say and Fitch observed and described species, Packard worked extensively with springtails, and in their earlier days Mac Gillivray and Banks added to our knowledge of North American forms.

Dr. Maynard, in this attractive book, has done a fine job in bringing together our knowledge of the Collembola of New York into a readable, useful handbook which will be of value to all entomologists, and especially to those working in the northeastern states.

In dealing with two-hundred species or forms Dr. Maynard has brought together the greatest variety of Collembola ever discussed in one North American treatise. Of these, fifty-seven are described as new and four new genera are erected.

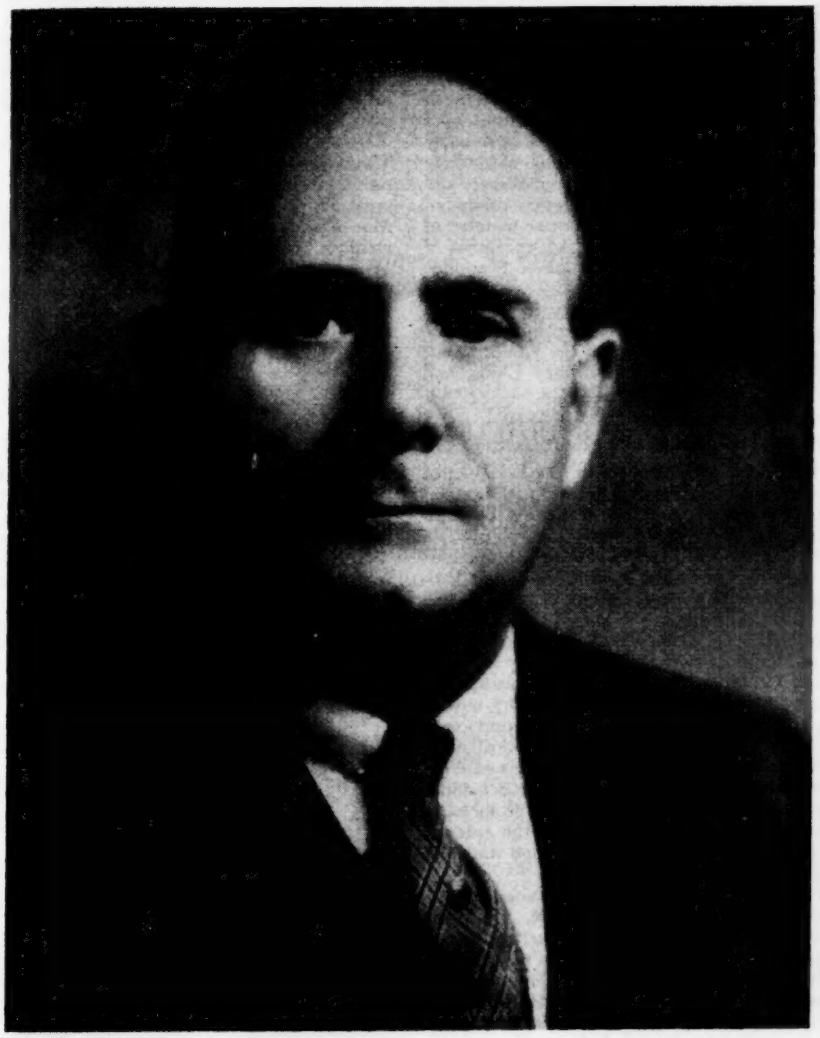
This book is more than a cold taxonomic treatment. The collections from New York in relation to the faunal areas of the state are discussed. There are sections on morphology, life history, habitat, abundance, food, and the like. A number of colored plates will be useful in making comparisons, and there is a total of 652 illustrations! The bibliography (pp. 291–330) is comprehensive and will save much time for future workers.

The specialist in this group will find a few things which could have been made more helpful. For example, the descriptions, especially of the new species, are somewhat sketchy and possibly dwell more on color and color pattern than these superficial characters warrant. The literature has not always been carefully checked. In establishing the genus *Semicerura* the author states when referring to dental spines (p. 99): "This is the first record of an Isotomid from North America with such spines." When James in 1933 described *Isotoma multispinata* from the Toronto region, he described similar structures and said, "This interesting form is distinguished at present from all other American Isotomas, by the presence of a spinous dens." In comparing illustrations it would appear that the two may be at least congeneric. Again (pp. 94–5) the genus *Metisotoma* is erected for two new species, *M. capitona* and *M. spiniseta*, with no mention of the old *Isotoma grandiceps* Reuter, described in 1891, redescribed by Mills (1934), and Folsom (1937), and quite clearly congeneric with it.

These are things which will settle themselves with time, and do not detract greatly from the over-all value of this book to entomologists throughout the world. Dr. Maynard is to be congratulated on this fine contribution to our knowledge of a poorly known group.

HARLOW B. MILLS
Illinois Natural History Survey

OBITUARIES



William Andrew Thomas

1883-1951

William A. Thomas died, following a brief illness, in a hospital at Conway, South Carolina on March 20, 1951. He was buried with Masonic honors in the Greenlawn Memorial Cemetery at Chadbourn, North Carolina.

William Andrew Thomas was born on a farm near Bennettsville, South Carolina October 1, 1883, and attended Welch Neck High School, now Coker College, at Hartsville, South Carolina. He received a B.S. degree in 1908 at Clemson College where he was a student and associate of A. F. Conradi. He was the first Clemson graduate to become a professional Entomologist. During the period 1908–18 he served at various times in the following capacities: Acting State Entomologist of South Carolina, Assistant Entomologist of the South Carolina Experiment Station, Assistant Professor of Zoology and Entomology at Clemson College, Extension Entomologist of North Carolina and an Agent of the U. S. Bureau of Entomology. From April 10, 1918 until he retired, April 30, 1945, he was continuously employed in the U. S. Bureau of Entomology and Bureau of Entomology and Plant Quarantine with the exception of one period of 10 months. After his retirement and up to the time of his death he operated the Thomas Pest Control Laboratory at Chadbourn, North Carolina and served as instructor of a War Veterans Agricultural Class at Cerro Gordo, North Carolina.

It can truly be said that Mr. Thomas had a wide experience in the field of Entomology. Fundamentally he was a teacher and as such possessed unusual ability to simplify and explain the various basic principles of applied entomology which are frequently little understood by farmers. It is not often that a man is encountered who has the con-

fidence and respect of such a large number of farmers and associates in the sphere of his activities as did Mr. Thomas. His patience and consideration, manifested under any and all conditions, did much to promote the application of entomological practices of immeasurable value to the farmers. In research Mr. Thomas was connected with the Division of Truck Crop and Garden Insests and primarily interested in insects of the garden. Much of his time was devoted to the study of strawberry insects and mole crickets and some of his findings were presented in publications on these insects. He was a member of the American Association for the Advancement of Science and the American Association of Economic Entomologists.

Mr. Thomas was always actively interested in the religious and civic affairs in his community. He was an active Mason, a patron of the Eastern Star, member of the Exchange and Rotary Clubs, and served on the school board and town council. He was particularly interested in his Sunday School classes where he had an excellent opportunity to make use of his ability as a teacher. His influence in his community has been profound as the result of his example and teachings in his Sunday School classes.

One of the most outstanding characteristics of Mr. Thomas was his devotion to his family. He was proud of his home and no sacrifice for it was too great. On October 19, 1910 he was married to Miss Mae Edens of Sumter, South Carolina. She, four children, Mrs. Alice Ashton of Raleigh, N. C., William Albert Thomas, Chadbourn, N. C., Mrs. Eleanor Howard of Oxford, N. C. and John Kent Thomas, a student of Clemson College, S. C., together with 12 grandchildren, survive.

C. F. STAHL AND W. J. REID, JR.

EDWARD A. SCHWING

It is with deep personal as well as official regret that the passing of Edward A. Schwing, Entomologist with the Spreckels Sugar Company of California, on June 16, 1951, is here recorded. His was a life time of service devoted to solving the complex control problem presented by the sugar beet leafhopper, which acts as a sole agent in transmitting the curly top virus to its hosts. This virus at one time threatened the very existence of the sugar beet industry and later caused extremely heavy losses to growers of tomatoes and other susceptible agricultural crops. During his field and laboratory studies associated with this problem which had previously taxed the thinking of some of the foremost entomologists in the country and his later successful application of the methods worked out. He developed not only a national reputation as an entomologist but a host of friends among those in the entomological profession throughout the nation and particularly in the Western States.

Ed was born in 1893 in Alsace-Lorraine, France, coming to this country at an early age. He graduated from the University of Illinois in 1916, with a degree in pomology, soon after moving to California where he first taught in the high school at Santa Barbara and later served as an instructor in pomology at the University of California at Davis. He joined the staff of the Spreckels Sugar Company in 1931 being employed to study the beet leafhopper-curly top virus problem to see what might be worked out in preventing further losses similar to those experienced during repeated outbreaks prior to that year.

As a result of his studies, which were carried on in close cooperation with State, Federal, and University research workers, who were also giving attention to the problem, he worked out an effective method of control which has been the major factor in preventing subsequently serious outbreaks with a tremendous saving to the agricultural industries concerned.

He was later loaned to the Department for the major part of two years to train State personnel in the techniques involved. With the permission of the Spreckels Sugar Company he continued to render in valuable advisory assistance in the conduct of these operations up to the time of his death.

In passing Ed leaves his wife, Leah B. Schwing, who is active in Women's civic affairs in Sacramento and recent President of their organized group, also a daughter, Mrs. George R. McGregor of Fresno, whose husband is Assistant Credit Manager for Standard Oil Company in that area; and their daughter Pamela, two and one-half years; a son, Lt. Robert G. Schwing, presently in Washington, D. C., as head to the Administrative Officer of Merchant Marines; and a son, Richard E. Schwing, who is entering Stanford University this fall as an architectural engineer.

Ed will be sincerely missed for a long time to come by the growers whom he has served so well and by his many co-workers.

Edward A. Schwing, 1893–1951